Calibration of the Biological Condition Gradient (BCG) for Fish Assemblages in Indiana Streams & Large Rivers

FINAL REPORT

Photos provided by IDEM

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EXECUTIVE SUMMARY

The objective of the Clean Water Act is to “restore and maintain physical, chemical and biological integrity of the Nation’s waters.” To meet this goal, we need a uniform interpretation of biological condition and operational definitions that are independent of different assessment methodologies. These definitions must be specific, well-defined, and allow for waters of different natural quality and different desired uses. The USEPA has outlined a condition gradient (the Biological Condition Gradient, or BCG) that describes how ecological attributes change in response to increasing levels of human-caused disturbance or stress. The Biological Condition Gradient is a conceptual model that describes changes in aquatic communities. It is consistent with ecological theory and has been verified by aquatic biologists throughout the United States.

Specifically, the BCG describes how ten biological attributes of natural aquatic systems change in response to increasing pollution and disturbance. The ten attributes are in principle measurable. However, a few of the attributes (e.g., ecosystem function, organism condition/health) are typically not measured by monitoring programs, but rather are inferred from other, more readily available measures. The gradient represented by the BCG has been divided into six BCG levels of condition that biologists think can be readily discerned in most areas of North America, ranging from “natural or native condition” (level 1) to “severe changes in structure and major loss of ecosystem function” (level 6).

This report summarizes the findings of a panel of aquatic biologists from the Indiana Department of Environmental Management (IDEM), Indiana Department of Natural Resources (IDNR), City of Elkhart, Muncie Sanitary District, Eastern Kentucky University, Ball State University, US Geological Survey (USGS), National Park Service (NPS) and Midwest Biodiversity Institute (MBI), who applied and calibrated the general BCG model to streams in Indiana. The panel was challenged to: 1) assign BCG attributes to fish species recorded in the dataset; and 2) achieve consensus in assigning stream reaches into BCG levels using the fish assemblage data. The rules used by the panelists were compiled, tested, refined, and vetted with the panel through a series of meetings and webinars. The end products were quantitative BCG models to predict the BCG level of a stream based on the rules developed by the panel. For sites with drainage areas less than 1000 mi^2, the BCG panel assigned 162 samples to BCG levels during the calibration exercise, and 40 more during the confirmation round. For large rivers (sites with drainage areas greater than 1000 mi^2), panelists assessed 25 samples during the calibration round and 9 samples to confirm the model. On average, the quantitative models were 98% accurate in replicating the panel assessments within one-half BCG level for the calibration data sets, and 94% accurate for the confirmation data. The Indiana fish BCG models are suited to supplement and enhance traditional assemblage level data analysis used for water quality assessments.

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ACRONYMS

ALU	Aquatic Life Use
BCG	Biological Condition Gradient
BMP	Best Management Practices
CCBP	Central Corn Belt Plains
CWA	Clean Water Act
ECBP	Eastern Corn Belt Plains
HELP	Huron/Erie Lake Plains
IBI	Index of Biological Integrity
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IP	Interior Plateau
IRL	Interior River Lowland
MBI	Midwest Biodiversity Institute
NIH	National Institutes of Health
ORSANCO	Ohio River Valley Water Sanitation Commission
SMNDIP	Southern Michigan/Northern Indiana Drift Plains
TALU	Tiered Aquatic Life Use
USEPA	U. S. Environmental Protection Agency
USGS	U. S. Geological Survey
WQS	Water Quality Standards

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1 INTRODUCTION

This document describes the calibration of assessment models for fish assemblages in the framework of the Biological Condition Gradient (BCG) for streams and rivers in Indiana, for use by the Indiana Department of Environmental Management (IDEM) in its biological assessment program. The U.S. Environmental Protection Agency (U.S. EPA) evaluated IDEM's biological assessment program in January 2014. The review provided information on the strengths and limitations of the bioassessment program, resource allocation and prioritization for improving the bioassessment program, and integration of biological assessments to more precisely describe aquatic life uses and develop numeric biological criteria. The models developed in this report address one of the principal recommendations of the review, to improve the rigor of IDEM's biological assessment program (U.S. EPA 2013).

The decision models described here incorporate multiple attribute decision criteria to assign streams to levels of the BCG. The models were developed using fish monitoring data from the IDEM. Participants included scientists from the IDEM, Indiana Department of Natural Resources (IDNR), City of Elkhart, Muncie Sanitary District, Eastern Kentucky University, Ball State University, US Geological Survey (USGS), National Park Service (NPS) and Midwest Biodiversity Institute (MBI). The Indiana fish BCG models can potentially be used to supplement and enhance the Indices of Biotic Integrity (IBI) and other measures that the IDEM currently uses to assess stream health.

1.1 Why Is Measuring Biological Condition Important?

A natural aquatic community and a surrounding, intact watershed provide many social and economic benefits such as food, recreation and flood control. The US Clean Water Act reflects this public priority by establishing a national goal to restore and maintain the chemical, physical and biological integrity of the Nation's waters (USEPA 2016). The term "biological integrity" has been defined in the literature to mean a balanced, integrated, adaptive system having a full range of ecosystem elements (e.g., genera, species, assemblages) and processes (e.g., mutation, demographics, biotic interactions, nutrient and energy dynamics, metapopulation dynamics) expected in areas with no or minimal human disturbance (Karr 2000).

Biological assessments are an evaluation of the biological condition of a waterbody using surveys of the structure and function of resident biota. The biota functions as a continual monitor of environmental quality, increasing the sensitivity of assessments by providing a continuous measure of exposure to anthropogenic stress. Field-based biological assessments capture the in-situ response of the resident biotic community to the sum of stressors to which that community is exposed (versus laboratory-based experiments, which are typically limited to a single species and specified doses of known chemicals) (U.S. EPA 2016).

1.2 The Biological Condition Gradient

"The Biological Condition Gradient (BCG) is a conceptual, scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems" (U.S. EPA 2016). The framework was developed based on common patterns of biological response to anthropogenic stressors observed empirically by aquatic biologists and ecologists from different geographic areas of the United States (Davies and Jackson 2006). It describes how measurable characteristics of aquatic ecosystems change in response to increasing levels of stress, from a natural condition (undisturbed or minimally disturbed by modern human activities) to severely altered conditions (highly disturbed). In the BCG framework, these measurable characteristics are defined as "attributes" of the biological communities and the physical habitat that reflect the condition of an aquatic ecosystem (U.S. EPA 2016). The attributes (Table 1) include properties of the system and communities (e.g., richness, structure, abundance, system functions) and organisms (e.g., tolerance, rarity, native-ness, physical condition).

The BCG framework defines levels of biological condition that increasingly differ from biological integrity (or natural condition) as defined above, as a response to increasing human disturbance. The levels were deemed to be both discernible (detectable) and to reflect biologically meaningful differences by the original expert panels that developed the conceptual BCG (Davies and Jackson 2006).

Throughout this document, our use of "disturbance" refers exclusively to human-caused or anthropogenic disturbance. We follow the definition of disturbance in U.S. EPA (2016): "Human activity that alters the natural state and can occur at or across many spatial and temporal scales." Stressors are "Physical, chemical, or biological factors that adversely affect aquatic organisms" (U.S. EPA 2016). Accordingly, human disturbance creates stressors in a system, which in turn may (or may not) cause stress in the exposed organisms or ecosystem. Natural events and processes also result in stressors and stress on organisms, but these are considered part of the natural background of the system.

Since completion of the conceptual BCG framework (Davies and Jackson 2006), many states have further developed and refined quantitative BCG models. In conjunction with other water quality management technical tools, the state programs that have developed and applied the BCG have done so to help (U.S. EPA 2016):

- Set scientifically defensible, ecologically-based aquatic life goals (ALUs) based on existing conditions and potential for improvement;
- Determine baseline conditions and measure impacts of multiple stressors or system altering conditions (e.g., climate change) on aquatic life;
- Further the use of monitoring data for the assessment of water quality standards (WQS) and tracking changes in biological condition (e.g, documentation of incremental improvements due to controls and best management practices (BMPs));
- Identify high quality waters for protection (e.g., Tier III antidegradation); and
- Communicate to stakeholders the likely impact of decisions on protection and management of aquatic resources."

BCG models are built on documented logic that can be followed by knowledgeable persons, resulting in transparent decision criteria for a state's assessment process. BCG levels are intended to be universal, so that a BCG Level 3 assessment means the same in Indiana as it does in, say, Minnesota. Documentation of the highest BCG Level – Level 1- represents an effort to prevent "shifting baselines", where human memory limits our ability to identify undisturbed conditions. Descriptions of how water quality programs in Minnesota, Alabama, Maryland, Pennsylvania, Maine and Ohio have used the BCG for assessment and in some cases, for setting tiered aquatic life uses (TALUs) in water quality standards (WQS), can be found in the BCG Practitioner's Guide (U.S. EPA 2016).

The BCG is divided into six levels of biological condition along the stress-response curve, ranging from observable biological conditions found at no or low levels of stress (level 1) to those found at high levels of stress (level 6) (Figure 1):

> **Level 1.** Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within range of natural variability. Level 1 describes waterbodies that are pristine, or biologically indistinguishable from pristine condition.
>
> **Level 2.** Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.
>
> **Level 3.** Some changes in structure due to loss of some highly sensitive native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system, but may differ quantitatively.
>
> **Level 4.** Moderate changes in structure due to replacement of intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes.
>
> **Level 5.** Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased buildup or export of unused organic materials.
>
> **Level 6.** Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor (e.g., diseased individuals may be prevalent); ecosystem functions are severely altered.

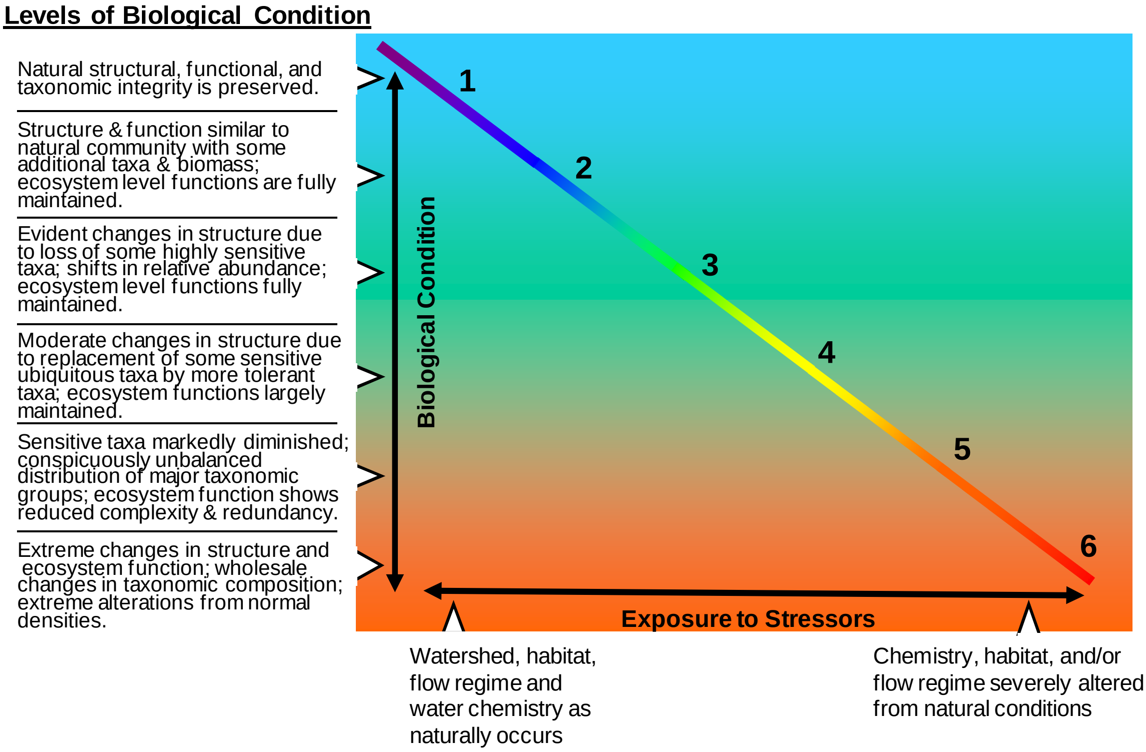


Figure 1. The Biological Condition Gradient (BCG), modified from Davies and Jackson 2006. The BCG was developed to serve as a scientific framework to synthesize expert knowledge with empirical observations and develop testable hypotheses on the response of aquatic biota to increasing levels of stress. It is intended to help support more consistent interpretations of the response of aquatic biota to anthropogenic stressors and to clearly communicate this information to the public, and it is being evaluated and piloted in several regions and states.

The scientific panels that developed the original BCG conceptual model identified 10 attributes of aquatic ecosystems that change in response to increasing levels of stressors along the gradient, from level 1 to 6 (see Table 1 and Figure 2). The attributes include several aspects of community structure, organism condition, ecosystem function, spatial and temporal characteristics of stressors, and connectivity (Davies and Jackson 2006).

Each attribute provides some information about the biological condition of a waterbody. Combined into a model like the BCG, the attributes can offer a more complete picture about current waterbody conditions and also provide a basis for comparison with naturally expected waterbody conditions. All of the states and tribes that have applied a BCG used the first six attributes that describe the composition and structure of biotic community on the basis of the tolerance of species to anthropogenic stressors (Table 1). Some have also used attributes VII (organism condition), VIII (ecosystem function) and X (ecosystem connectivity), pending availability of data that characterize those attributes.

The last three BCG attributes of ecosystem function, connectivity, and spatial and temporal extent of detrimental effects can provide valuable information when evaluating the potential for a waterbody to be protected or restored. For example, a manager can choose to target resources and restoration activities to a stream where there is limited spatial extent of anthropogenic stressors or there are adjacent intact wetlands and stream buffers or intact hydrology versus a stream with comparable biological condition but where adjacent wetlands have been recently eliminated, hydrology is being altered, and stressor input is predicted to increase.

Table 1. Biological and other ecological attributes used to characterize the BCG.

Attribute	Description
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	Taxa known to have been supported according to historical, museum, or archeological records, or taxa with restricted distribution (occurring only in a locale as opposed to a region), often due to unique life history requirements (e.g., Pupfish, many Unionid mussel species).
II. Highly sensitive (typically uncommon) taxa	Taxa that are highly sensitive to pollution or anthropogenic stressors. Tend to occur in low numbers, and many taxa are specialists for habitats and food type. These are the first to disappear with disturbance or pollution (e.g., most stoneflies, Brook Trout [in the east], Brook Lamprey).
III. Intermediate sensitive and common taxa	Common taxa that are ubiquitous and abundant in relatively undisturbed conditions but are sensitive to anthropogenic stressors. They have a broader range of tolerance than Attribute II taxa and can be found at reduced density and richness in moderately disturbed sites (e.g., many mayflies, many darter fish species).
IV. Taxa of intermediate tolerance	Ubiquitous and common taxa that can be found under almost any conditions, from undisturbed to highly stressed sites. They are broadly tolerant but often decline under extreme conditions (e.g., filter-feeding caddisflies, many midges, many minnow species).
V. Highly tolerant taxa	Taxa that typically are uncommon and of low abundance in undisturbed conditions but that increase in abundance in disturbed sites. Opportunistic species able to exploit resources in disturbed sites. These are the last survivors (e.g., tubificid worms, Black Bullhead).
VI. Nonnative or intentionally introduced species	Any species not native to the ecosystem (e.g., Asiatic clam, zebra mussel, carp, European Brown Trout). Additionally, there are many fish native to one part of North America that have been introduced elsewhere.
VII. Organism condition	Anomalies of the organisms; indicators of individual health (e.g., deformities, lesions, tumors).
VIII. Ecosystem function	Processes performed by ecosystems, including primary and secondary production; respiration; nutrient cycling; decomposition; their proportion/dominance; and what components of the system carry the dominant functions. For example, shift of lakes and estuaries to phytoplankton production and microbial decomposition under anthropogenic eutrophication.
IX. Spatial and temporal extent of detrimental effects	The spatial and temporal extent of cumulative adverse effects of anthropogenic stressors; for example, groundwater pumping in Kansas resulting in change in fish composition from fluvial dependent to sunfish.
X. Ecosystem connectivity	Access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation. For example, levees restrict connections between flowing water and floodplain nutrient sinks (disrupt function); dams impede fish migration, spawning. Extensive burial of headwater streams leads to cumulative downstream impacts to biota through energy input disruption, habitat modification, and loss of refugia and dispersing colonists. Some taxa are considered to be indicative of connectivity, especially migratory fish such as Sturgeon, American Eel, Skipjack Herring (their presence indicates unbroken connectivity).

Source: Modified from Davies and Jackson 2006.

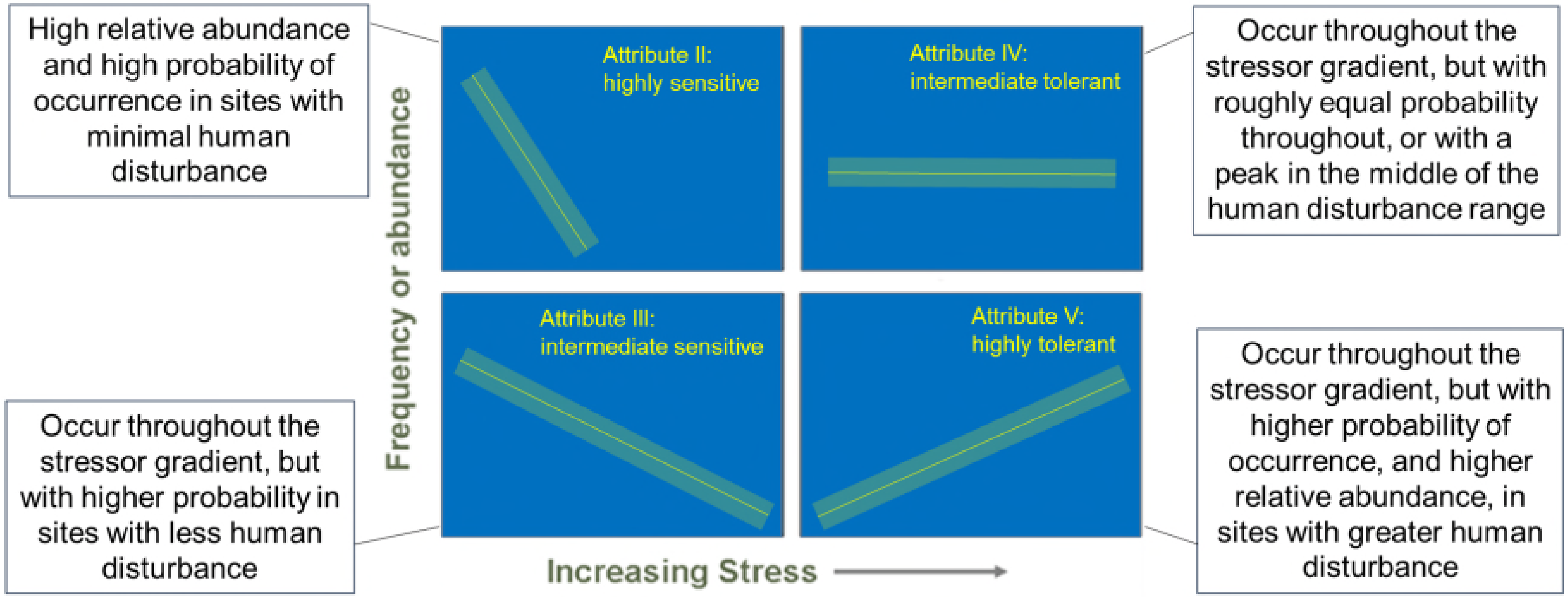


Figure 2. The frequency of occurrence and abundances of Attribute II, III, IV and V taxa are expected to follow these patterns in relation to the anthropogenic stressor gradient.

Existing indexes tend to rely heavily on empirical, present-day reference conditions, as quantified from existing reference sites. The objective is to identify “minimally disturbed” reference sites that are representative of biological integrity (Stoddard et al. 2006); in practice however, most reference site datasets consist of “least disturbed” sites, that is, the most natural that are left, but nevertheless may be subject to substantial human disturbance. The distinction between “minimally disturbed” and “least disturbed” is important: “minimally disturbed” denotes fully natural biological conditions indistinguishable from pre-industrial or pre-European settlement; while “least disturbed” denotes an upper quantile of contemporary conditions (Stoddard et al. 2006). Most indexes are built from a statistically adequate sample of reference sites. In some cases (depending on the statistical technique that is used) one or two minimally disturbed sites (still maintaining natural biological integrity) in a reference data set might be treated as statistical outliers, which may cause them to have little influence on index scoring. In the situation where all reference sites are disturbed to some extent, the highest (most natural) score of a resultant index would be similar to the moderately disturbed reference sites, and could already be well down the biological condition gradient shown in Figure 1. Because the baseline has shifted away from pre-disturbance conditions in many locations, and knowledge of historical ecology is often limited, it can be difficult to set accurate expectations for least disturbed sites.

Part of the BCG process is to build a description of a fixed baseline: “minimally disturbed” conditions (sensu Stoddard et al. 2006) from a fixed, agreed-upon point in time (November 28, 1975, according to federal WQ regulations) (U.S. EPA 2016). The description should be based on professional judgment, historical descriptions, paleo investigations, and museum records (to the extent available), as well as information from contemporary, empirical least disturbed sites. The description of minimally disturbed is necessarily incomplete, but its documentation is a defense against future baseline shifts, as well as identification of initial data and judgment for forming the baseline, should additional information become available. Careful use of the BCG identifies a natural or historic baseline that can be used to guard against “shifting baseline syndrome.” For regions or situations where all information on natural baseline is irretrievably lost, the BCG can assist in identifying an “Anthropocene baseline” for restoration and desired management (Kopf et al. 2015).

The BCG:

- Creates a consistent interpretation of biological condition - the six defined BCG levels are intended to be consistent across aquatic ecosystem classes, such that BCG level 1 is equivalent to undisturbed, i.e., the biological integrity objective in the context of the US Clean Water Act.

- Describes a continuous scale of condition from undisturbed (level 1) to highly disturbed conditions (level 6).

- Synthesizes existing field observations and generally accepted interpretations of patterns of biological change within a common framework.

- Helps determine the degree to which a system has departed from undisturbed condition, based on measurable, ecologically important attributes.

The above properties enable federal, state, tribal and local agencies to:

- **Define goals for a waterbody—**Information on the composition of a naturally occurring aquatic community can provide a description of the expected biological condition for other similar waterbodies and a benchmark against which to measure the biological integrity of surface waters. A few states and tribes have used such information to more precisely define their designated aquatic life uses, develop biological criteria, and measure the effectiveness of controls and management actions to achieve those uses.

- **Report status and trends—**Depending on level of effort and detail, biological assessments can provide information on the status of the condition of the expected aquatic biota in a waterbody and, over time with continued monitoring, provide information on long-term trends.

- **Identify high-quality waters and watersheds—**Biological assessments can be used to identify high-quality waters and watersheds and support implementation of anti-degradation policies.

2 METHODS AND DATA

2.1 Calibrating of the Conceptual BCG Model to Local Conditions

A multistep process is followed to calibrate a BCG to local conditions (Figure 3): describe the native aquatic assemblages under natural conditions; identify the predominant regional anthropogenic stressors; and describe the BCG, including the theoretical foundation and observed assemblage response to anthropogenic stressors. BCG development requires professional judgment and development of consensus (U.S. EPA 2016). Assessing condition of biological communities, including all common biotic indexes, involves professional judgment, even though such judgment may be hidden in apparently objective, quantitative approaches. Professional judgment is applied in the development of all assessment frameworks (e.g., Steedman 1994, Borja et al. 2004, Weisberg et al. 2008). Use of professional consensus has a long pedigree in the medical field, including the National Institutes of Health (NIH) Consensus Development Conferences to recommend best practices for diagnosis and treatment of diseases (NIH http://consensus.nih.gov/).

BCG calibration begins with the assembly and analysis of biological monitoring data. Next, a calibration workshop is held in which experts familiar with local conditions use the data to define the ecological attributes and set narrative statements (for example, narrative decision rules for assigning sites to a BCG level on the basis of the biological information collected at sites). Documentation of expert opinion in assigning sites to BCG levels is a critical part of the process. A decision model can then be developed that encompasses those rules and is tested with independent data sets. A decision model based on the tested decision rules is a transparent, formal, and testable method for documenting and validating expert knowledge. A quantitative data analysis program can then be developed using those rules.

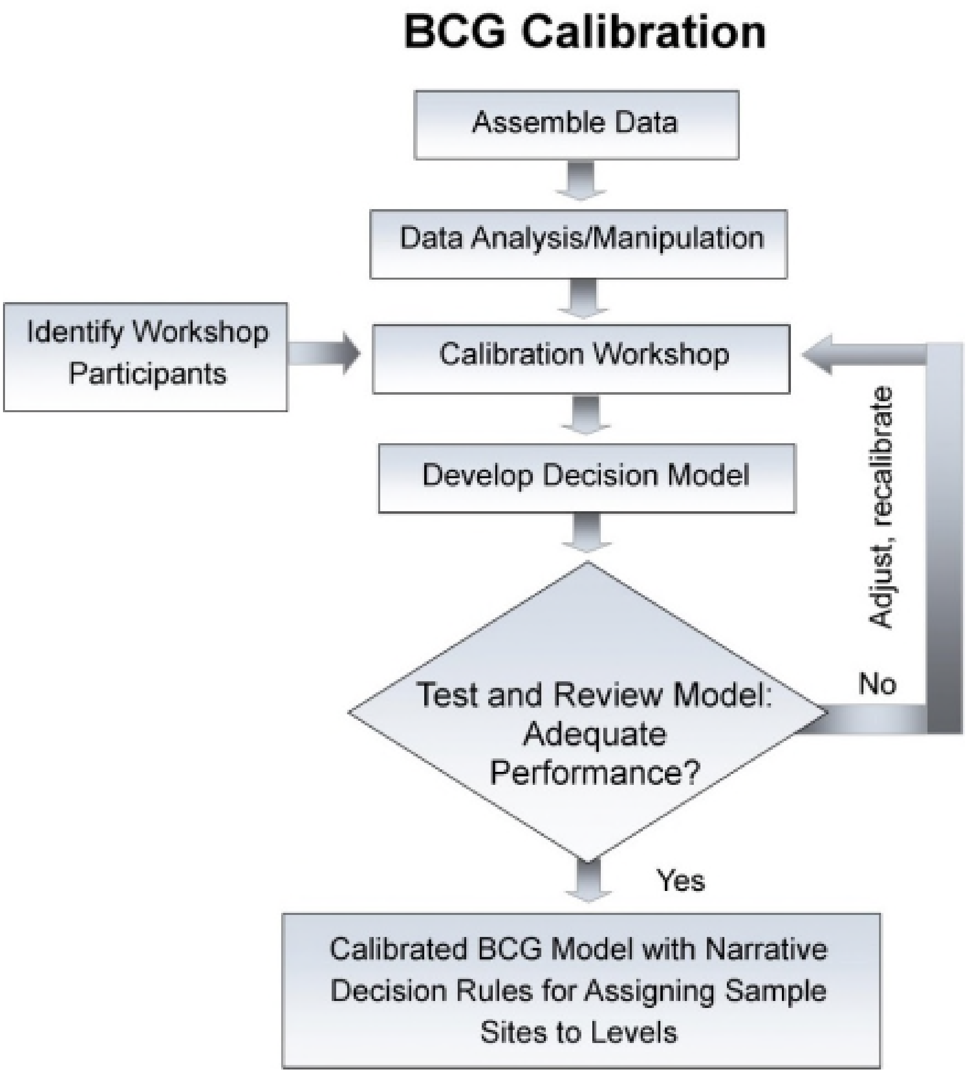


Figure 3. Steps in a BCG calibration.

2.1.1 Assign Sites to Levels

The conceptual model of the BCG is intended to be universal (U.S. EPA 2016, Davies and Jackson 2006), but descriptions of communities, species, and their responses to the anthropogenic stress gradient are specific to the conditions and communities found in the sample region. Before assigning sites to BCG levels, the expert panel begins by describing the biological condition levels that can be discerned within their region. The description of natural conditions requires biological knowledge of the region, a natural classification of the assemblages, and, if available, historical descriptions of the habitats and assemblages.

The panelists examine species composition and abundance data from sites with different levels of cumulative stress, ranging from least stressed to severely stressed. The panel works with data tables showing the species and attributes for each sample. In developing assessments, the panel works “blind”, that is, no stressor information is included in the data table. Only non-anthropogenic classification variables are shown (e.g., stream size, sample date). Panel members discuss the species composition and what they expect to see for each level of the BCG (e.g., “I expect to see more darter taxa in a BCG level 2 site”), and then assign samples to BCG levels. These site assignments are used to describe changes in the aquatic communities for a range of anthropogenic stress, leading to a complete descriptive model of the BCG for the region.

2.1.2 Quantitative Description

BCG level descriptions in the conceptual model tend to be general (e.g., “reduced richness”). To allow for consistent assignments of sites to levels, it is necessary to formalize the expert knowledge by codifying level descriptions into a set of rules (e.g., Droesen 1996). If formalized properly, a knowledgeable person (with data) can follow the rules to obtain the same level assignments as the group of experts. This makes the actual decision criteria transparent to stakeholders.

Rules are logic statements that experts use to make their decisions (for example, “If taxon richness is high, then biological condition is natural”). Rules on attributes can be combined, for example: “If the number of highly sensitive taxa (Attribute II) is high, <u>and</u> the number of tolerant individuals (Attribute V) is low, then assignment is level 2.”

Numeric rule development requires discussion and documentation of level assignment decisions and the reasoning behind the decisions. During this discussion, it is necessary to record each participant’s level decision (e.g., vote) for the site, the critical or most important information for the decision (e.g., the number of taxa of a certain attribute, the abundance of an attribute, the presence of indicator taxa), and any confounding or conflicting information and how this was resolved for the eventual decision.

As the panel assigns example sites to BCG levels, the members are polled on the critical information and criteria they use to make their decisions. These form preliminary, narrative rules that explain how panel members make decisions. For example, “For BCG level 2, sensitive taxa must make up half or more of all taxa in a sample.” The decision rule for a single level of the BCG does not always rest on a single attribute (e.g., highly sensitive taxa) but may include other attributes as well (intermediate sensitive taxa, tolerant taxa, indicator species), so these are termed “Multiple Attribute Decision Rules.” With data from the sites, the rules can be checked and quantified. Quantification of rules allows users to consistently assess sites according to the same rules used by the expert panel, and allows a computer algorithm, or other persons, to obtain the same level assignments as the panel.

Rule development requires discussion and documentation of BCG level assignment decisions and the reasoning behind the decisions. During this discussion, we record:

- Each participant’s decision (“vote”) for the site
- The critical or most important information for the decision—for example, the number of taxa of a certain attribute, the abundance of an attribute, the presence of indicator taxa, etc.

- Any confounding or conflicting information and how this was resolved for the eventual decision

Following the initial site assignment and rule development, we develop descriptive statistics of the attributes and other biological indicators for each BCG level determined by the panel. These descriptions assist in review of the rules and their iteration for testing and refinement.

Rule development is iterative, and may require 2 or more panel sessions. Following the initial development phase, the draft rules are tested by the panel with new data to ensure that new sites are assessed in the same way. The new test sites are not used in the initial rule development and also should span the range of anthropogenic stress. Any remaining ambiguities and inconsistencies from the first iterations are also resolved.

2.1.3 Decision Criteria Models

Consensus professional judgment used to describe the BCG levels can take into account nonlinear responses, uncommon stressors, masking of responses, and unequal weighting of attributes. This is in contrast to the commonly-used biological indexes, which are typically unweighted sums of attributes (e.g., multimetric indexes; Barbour et al. 1999, Karr and Chu 1999), or a single attribute, such as observed to expected taxa (e.g., Simpson and Norris 2000, Wright 2000). Consensus assessments built from the professional judgment of many experts result in a high degree of confidence in the assessments, but the assessments are labor-intensive (several experts must rate each site). It is also not practical to reconvene the same group of experts for every site that is monitored in the long term. Since experts may be replaced on a panel over time, assessments may in turn “drift” due to individual differences of new panelists. Management and regulation, however, require clear and consistent methods and rules for assessment, which do not change unless deliberately reset.

Use of the BCG in routine monitoring and assessment thus requires a way to automate the consensus expert judgment so that the assessments are consistent. The expert rules are automated in decision models. These models replicate the decision criteria of the expert panel by assembling the decision rules using logic and set theory, in the same way the experts used the rules. Instead of a statistical prediction of expert judgment, this approach directly and transparently converts the expert consensus to automated sample assessment. The method uses modern mathematical set theory and logic (called “fuzzy set theory”) applied to rules developed by the group of experts. Fuzzy set theory is directly applicable to environmental assessment, and has been used extensively in engineering applications worldwide (e.g., Demicco and Klir 2004) and environmental applications have been explored in Europe and Asia (e.g., Castella and Speight 1996, Ibelings et al. 2003).

Mathematical fuzzy set theory allows degrees of membership in sets, and degrees of truth in logic, compared to all-or-nothing in classical set theory and logic. Membership of an object in a set is defined by its membership function, a function that varies between 0 and 1. To illustrate, we compare how classical set theory and fuzzy set theory treat the common classification of sediment, where sand is defined as particles less than or equal to 2.0 mm diameter, and gravel is greater than 2.0 mm (Demicco and Klir 2004). In classical “crisp” set theory, a particle with diameter of 1.999 mm is classified as “sand”, and one with 2.001 mm diameter is classified as “gravel.” In fuzzy set theory, both particles have nearly equal membership (approximately 0.5) in both classes (Demicco and Klir 2004). Very small measurement error in particle diameter greatly increases the uncertainty of classification in classical set theory, but not in fuzzy set theory (Demicco and Klir 2004). Demicco and Klir (2004) proposed four reasons why fuzzy sets and fuzzy logic enhance scientific methodology:

- Fuzzy set theory has greater capability to deal with “irreducible measurement uncertainty,” as in the sand/gravel example above.
- Fuzzy set theory captures vagueness of linguistic terms, such as “many,” “large” or “few.”
- Fuzzy set theory and logic can be used to manage complexity and computational costs of control and decision systems.
- Fuzzy set theory enhances the ability to model human reasoning and decision-making, which is critically important for defining thresholds and decision levels for environmental management.

Rule-based Inference Model

People tend to use strength of evidence in defining decision criteria, and in allowing some deviation from their ideal for any individual attributes, as long as most attributes are in or near the desired range. For example, the definitions of “high,” “moderate,” “low,” etc., are qualitative (but ordinal) and can be interpreted and measured to mean different things. An important step in the BCG process is development of expert consensus defining these, or other, general terms and documenting the expert logic that is the basis for the decisions. The decision rules preserve the collective professional judgment of the expert group and set the stage for the development of models that can reliably assign sites to levels without having to reconvene the same group. In essence, the rules and the models capture the panel’s collective decision criteria.

An inference model is developed to replicate the panel decision process, and this section describes an inference model that uses mathematical fuzzy logic to mimic human reasoning. Each linguistic variable (e.g., “high taxon richness”) must be defined quantitatively as a fuzzy set (e.g., Klir 2004). For the BCG rules, we set lower and upper (“fuzzy set”) bounds for each metric based on information we gather from the calibration dataset. Each metric receives a membership value ranging from 0 to 1, depending on where the value falls in relation to the bounds. The rule threshold falls in the middle of these bounds. Metric values that are less than or equal to the lower bound receive a membership value of 0, while metric values that are greater than or equal to the upper bound receive a membership value of 1. In the example shown in Figure 4, the BCG rule for total taxa richness is ≥ 20 (15-25) (the lower bound is 15 and the upper bound is 25), which means –

- If there are 15 or fewer total taxa in the sample, the metric membership value is 0.
- If there are 25 or more total taxa in the sample, the metric membership value is 1.
- If the number of total taxa falls within the lower and upper bounds, the metric membership value will range from 0 to 1 (e.g., if there are 20 total taxa, the membership value will be 0.5; if there are 17 total taxa, the membership value will be 0.2; if there are 23 total taxa, the membership value will be 0.8).

BCG rules for a given level are typically comprised of multiple metrics (which are considered in combination). To illustrate this, Figure 4 also shows a second metric – percent sensitive taxa. In this example, the BCG rule for percent sensitive taxa is ≥ 10% (5-15) (the lower bound is 5% and the upper bound is 15%). The metric membership value is derived using the same procedure described above for the total taxa metric. If the two rules are combined with an “AND” operator, then both metrics must meet the thresholds for a given BCG level (in this example, total taxa richness must be ≥ 20 AND percent sensitive taxa must be ≥ 10%). The membership for the level will be the least of the membership levels for the two metrics. If the two rules are combined with an “OR” operator (referred to as an ‘alternate’ rule), then either can be true for a sample to meet the requirements (both conditions are not necessary). The membership for the level will be the greatest of the membership levels for the two metrics.

Together the rules for each BCG level work as a logical cascade from BCG level 1 to level 6, such that a sample is first tested against the level 1 rules; if the combined rule fails, then the level fails, and the assessment moves down to level 2, and so on (Figure 5). The BCG model evaluates metric membership values for all the metrics included in the rules for a given BCG level and considers the combination rules to derive the membership level for the sample. For example, if there are two rules (like shown in Figure 4) for BCG level 3 and they are joined with an “AND” operator, and the metric membership value for one metric is 0.8 and the metric membership value for the other is 0.6, the minimum membership value across the two metrics (0.6) is used to determine whether the requirements for a given BCG level are being met. If the two metrics are joined with an “OR” operator, then the BCG model considers the higher membership value (in this example, 0.8). The final BCG output may include membership of a sample in a single level only (e.g., probability of membership in BCG level 3 = 1.0), ties between levels (e.g., probability of membership in BCG level 3 = 0.5 and BCG level 4 = 0.5), and varying memberships among two or more levels (e.g., probability of membership in BCG level 3= 0.8 and probability of membership in BCG level 4 = 0.2). The level with the highest membership value is taken as the nominal level.

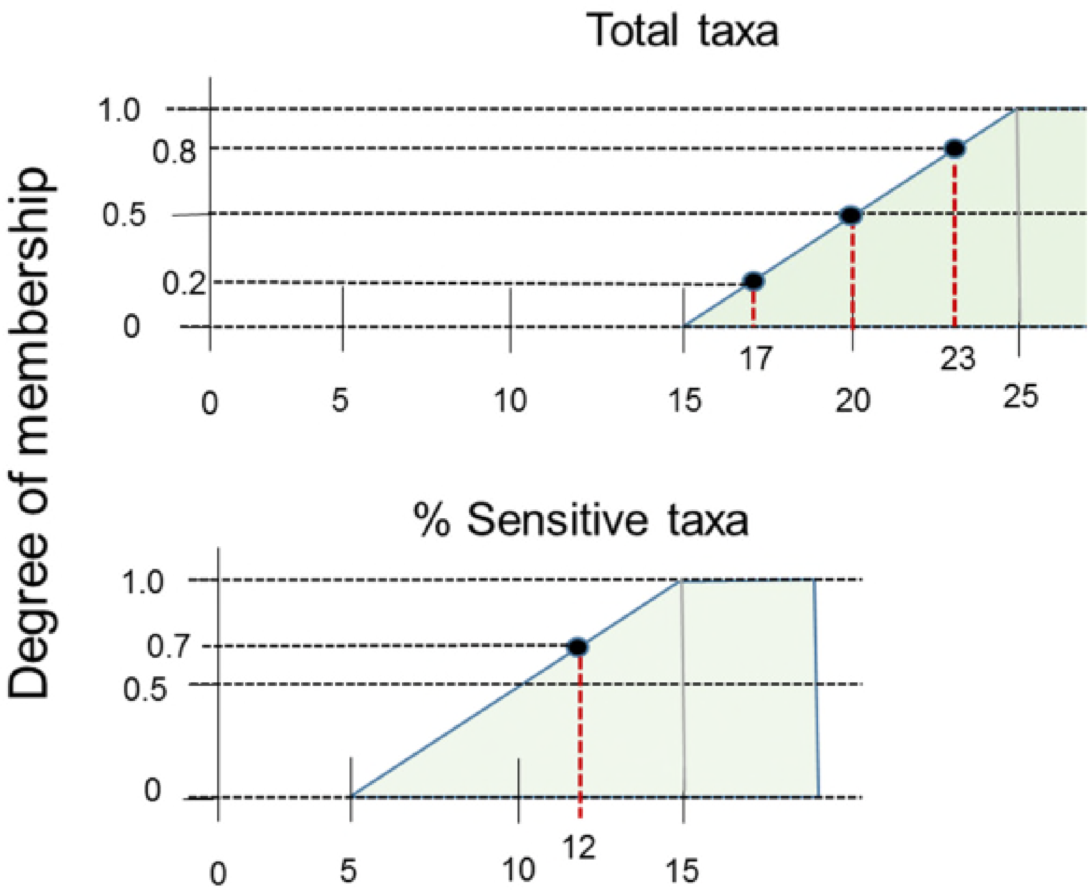


Figure 4. Illustration of the lower and upper ("fuzzy set") bounds for two metrics (total taxa richness and percent sensitive taxa). Each metric receives a membership value ranging from 0 to 1, depending on where the value falls in relation to the bounds. In this example, the BCG rule for total taxa richness is ≥ 20 (15-25) (the lower bound is 15 and the upper bound is 25), and the rule for percent sensitive taxa is ≥ 10 (5-15). The black dots show examples of metric membership values assigned to different metric values (e.g., for the total taxa metric, if there are 20 total taxa, the metric membership value will be 0.5; if there are 17 total taxa, the membership value will be 0.2; if there are 23 total taxa, the membership value will be 0.8; for the percent sensitive taxa metric, if the metric value is 12%, the membership value will be 0.7).

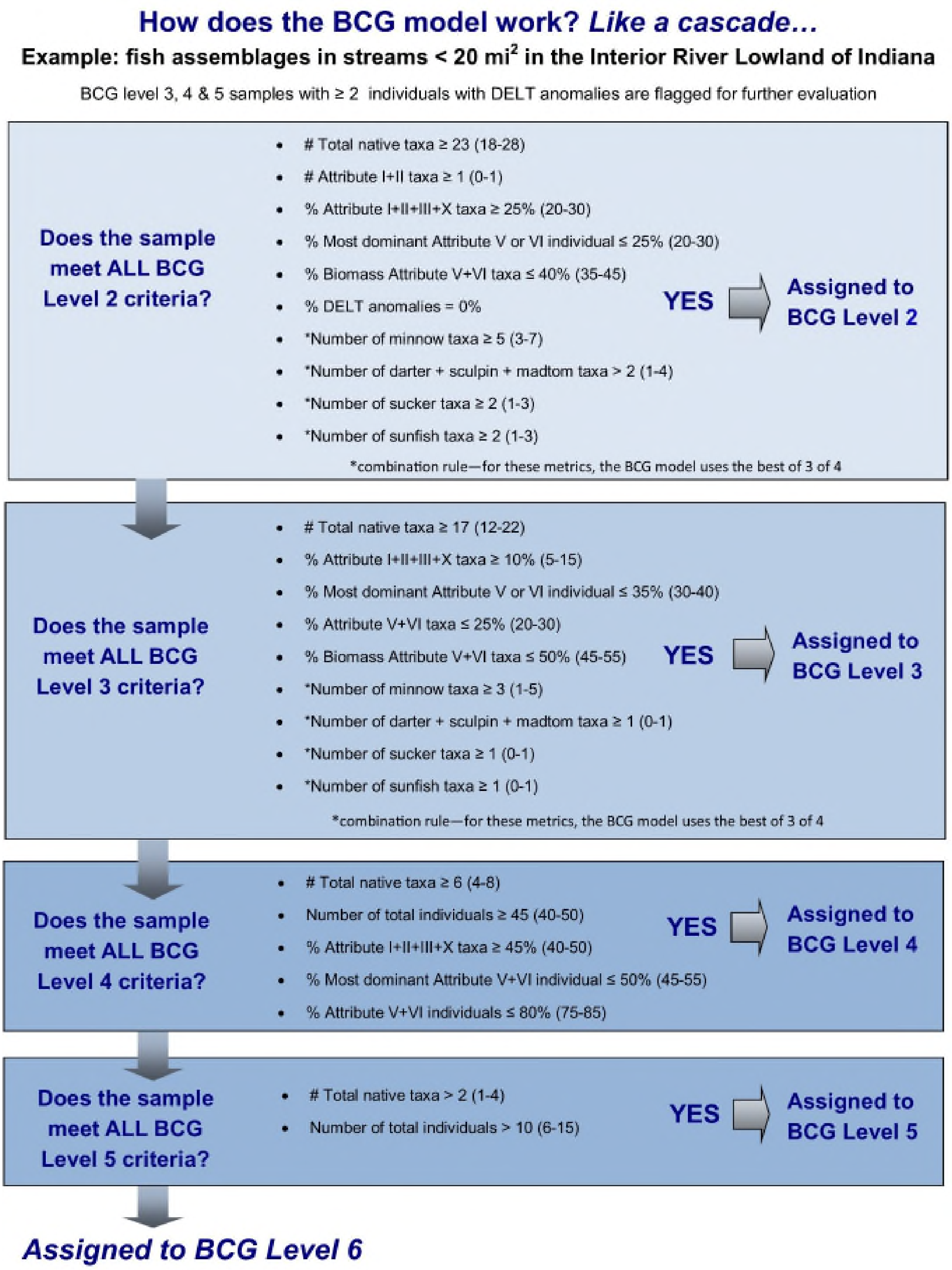


Figure 5. Example flow chart depicting how rules work as a logical cascade in the BCG model. This example is for fish assemblages in streams <20 mi^2 in the Interior River Lowlands ecoregion of Indiana (the flow chart starts with BCG level 2 because panelists did not assign any samples in this region to BCG level 1).

2.2 Fish Data

All data were provided by IDEM. The fish dataset consisted of 1899 samples from 1743 unique sites. Sampling years ranged from 1996-2013, with collection dates ranging from late May to mid-October. For the BCG calibration, the dataset was limited to samples collected from 2003 onward. For the BCG exercise, sites with drainage areas ≥ 1000 mi^2 were broken out into a ‘large rivers’ dataset, which consisted of 67 samples.

The IDEM samples from streams with drainage areas < 1000 mi^2 were collected using a variety of electrofishing methodologies (depending on stream size and accessibility), as summarized in Table 2 (and in greater detail in Appendix A). The sampling reach was 15 times the average wetted width, with a minimum reach of 50 meters and a maximum reach of 500 meters. All available habitat types were sampled. Fish were collected with dipnets with 1/8-inch bag mesh netting. Fish were sorted, weighed, identified to the species-level (when practical) and counted in the field. Young-of-the year fish less than 20 millimeters (mm) total length were not counted in the sample. Fish not readily identified in the field were preserved and later identified in the laboratory by IDEM staff. Sampling was not conducted during high flow or turbid conditions, or when seasonal cold temperatures occurred.

The IDEM large river samples were collected during the daytime from a 16’ or 17’ aluminum johnboat outfitted with a 5000W generator and Smith-Root VI-A electrofisher producing pulsed DC at 340 volts between 3-6 amps. Two electrofishing runs (one on each bank) were made at each site, with sampling distances of 15 times the stream width (up to a maximum of 500m). The older large river samples in the BCG dataset (pre-2008) were collected by crews that sampled in an upstream direction; from 2008 onward, crews sampled in a downstream direction. IDEM sampled all habitat types available to fish within the reach including sandy shorelines, logs/woody debris (even those away from the shoreline), and circled around to net fish behind the boat. For a 500 meter reach, crews generally electrofished 1800 seconds on each bank for a total of 3600 seconds. Crews had two netters.

In addition, panelists assessed 5 large river samples from the Kankakee and Wabash Rivers collected by MBI and the Ohio River Valley Water Sanitation Commission (ORSANCO) (Tewes et al., no date). These sites overlapped with large river boatable sites that had been sampled by IDEM, and BCG assessment results were compared to evaluate whether differences in each agency’s collection methods affected the results. The MBI/ORSANCO large river samples were collected during the daytime in the Kankakee and during nighttime in the Wabash. Daytime samples were collected using a 16' aluminum johnboat outfitted with a Smith-Root 5.0 GPP electrofisher (5000W) producing pulsed DC at 0-500 (low) or 0-1000 (high) volts between 0-25 amps. Nighttime samples were collected with the same equipment, but in a 19.5' aluminum johnboat. Two 500-meter passes were made at each site. Crews maneuvered the electrofishing boat slowly and methodically in and around submerged cover in a downstream direction along the shoreline. At a minimum, crews spent 2500 seconds of electrofishing time (time during which current is actively applied to water) for 500 meters, but this ranged upwards to 3000-3500 seconds where there were extensive instream cover and slack flows. Crews had two netters (Tewes et al., no date).

Table 2. Summary of streams < 1000 mi2 (assessed during calibration and confirmation).

Collection gear	Number of samples	Watershed Area (mi^2)		
		Minimum	Mean	Maximum
Backpack	36	1.2	21.7	126.0
Longline	84	1.0	25.4	218.3
Canoe/scanoe	64	9.6	153.0	510.0
Boat	19	77.3	518.6	915.4

Figure 6. IDEM uses a variety of electrofishing methodologies, depending on stream size and accessibility, including: boat electrofishing (upper photo; Ali Meils and Kevin Crane on the Whitewater River); canoe electrofishing (lower left; Patoka River); and longline (lower right; Kevin Crane at Fall Creek).

2.3 Classification

Experience has shown that a robust biological classification is necessary to calibrate the BCG, because the natural biological class indicates the species expected to be found in undisturbed, natural sites. As an example, low-gradient prairie or wetland-influenced streams typically contain species that are adapted to slow-moving water and often to hypoxic conditions. These same species found in a high-gradient, forested streams could indicate habitat degradation and organic enrichment.

For the BCG exercise, the fish experts used a classification scheme based on U.S. EPA level 3 ecoregions (Omernik 1987). BCG models were developed for the following 4 stream classes (Figure 7):

- (combined) Eastern Corn Belt Plains (ECBP) (ecoregion 55) + Interior Plateau (IP) (ecoregion 71)[1]
- Interior River Lowlands (IRL) (ecoregion 72)
- Central Corn Belt Plains (CCBP) (ecoregion 54)
- Southern Michigan/Northern Indiana Drift Plains (SMNIDP) (ecoregion 56)

Also, a separate BCG model was calibrated for large rivers (sites with drainage areas ≥ 1000 mi^2), which spanned ecoregions. The Huron/Erie Lake Plains (HELP) ecoregion was excluded from the BCG exercise because there were not enough sites to calibrate a BCG model specific to this area.[2]

Stream size, which is closely related to collection method, exerts a major influence on the longitudinal shift in fish assemblages (Figure 8). To account for differences in total taxa richness related to stream size, streams with drainage areas < 1000 mi^2 were further divided into sites that had drainage areas < 20 mi^2 and those with drainage areas ≥ 20 mi^2. The smaller streams are generally more prone to intermittency, particularly in southern part of the state, where streams generally have low base flow (Figure 9).

[1] Panelists at the March 30-April 1, 2015 workshop in Indianapolis felt that the biological assemblages in these two ecoregions were similar enough to combine for purposes of BCG model development.

[2] Samples from the HELP ecoregion can be run through any of the existing BCG models but results should be interpreted with caution since they are outside the bounds of experience of the model.

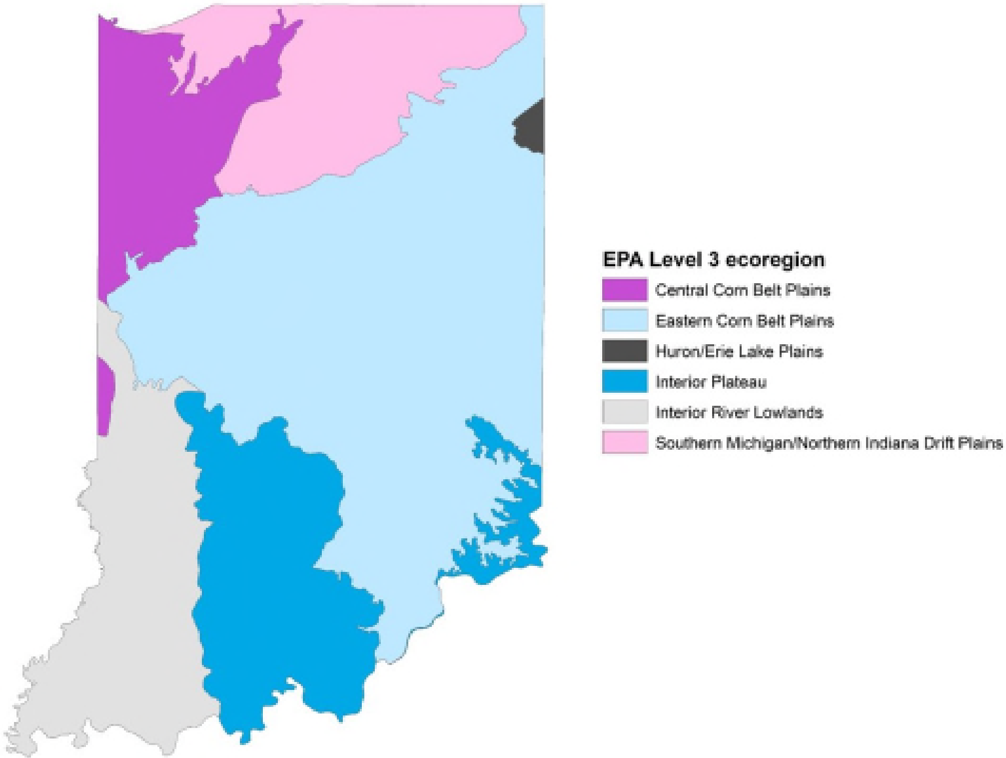


Figure 7. Fish BCG models were developed for 4 broad geographic areas, which were based on Level 3 ecoregions: Central Corn Belt Plains, Southern Michigan/Northern Indiana Drift Plains, Interior River Lowlands and Eastern Corn Belt Plains + Interior Plateau (Omernik 1987).

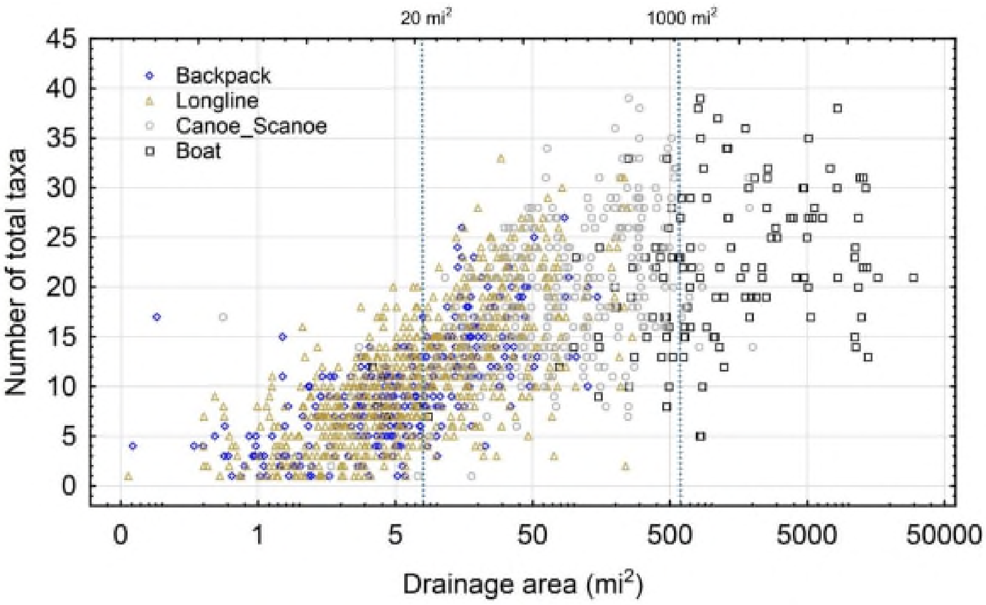


Figure 8. Scatterplots of total taxa richness vs drainage area (mi2). Samples are coded by collection gear. The x-axis is log-transformed. The vertical lines denote the stream size categories (headwaters < 20 mi^2; large rivers ≥ 1000 mi^2). Plots are based on the IDEM fish dataset.

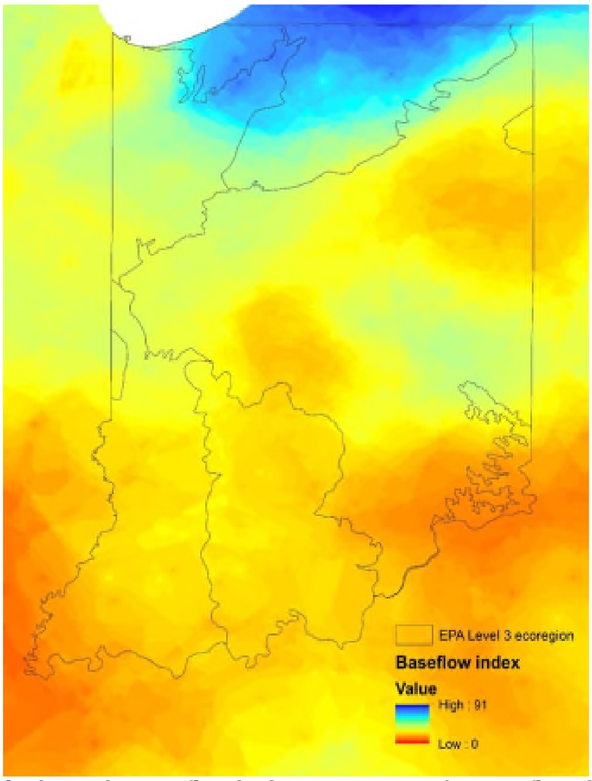


Figure 9. Base flow index (Wolock 2003). Base flow is the component of streamflow that can be attributed to ground-water discharge into streams. Low values (which correspond with the areas shown in red) indicate little if any base flow.

2.4 BCG Calibration Exercise

Calibration of the BCG for a region is a collective exercise among regional biologists to develop consensus assessments of sites, and then to elicit the rules that the biologists use to assess the sites (Davies and Jackson 2006). From March 30-April 1, 2015, regional biologists met at IDEM conference room facilities in Indianapolis, IN for a three-day workshop. The biologists had expertise in stream ecology and fish community assessments, and included scientists from the IDEM, IDNR, City of Elkhart, Muncie Sanitary District, Eastern Kentucky University, Ball State University, USGS, NPS and MBI. Fifteen panelists participated in the workshop. The goal was to develop a set of decision criteria rules for assigning fish samples to the BCG levels for streams in Indiana.

During this workshop, panelists first assigned BCG attributes to fish taxa (Tables 3-4, Figure 10, Appendix B). Table 3 contains a summary of how many fish taxa were assigned to each attribute group. Examples of taxa that were assigned to each attribute group are listed in Table 4. Prior to making attribute assignments, panelists reviewed plots showing the capture probabilities of fish taxa versus stress gradients to help inform their decisions (Appendix C).

Next, the panelists examined biological data from individual sites and assigned those samples to levels 1 to 6 of the BCG. The intent was to achieve consensus and to identify rules that experts were using to make their assignments. The data that the experts examined when making BCG level assignments were provided in worksheets. The worksheets contained lists of taxa, taxa abundances, BCG attribute levels assigned to the taxa, BCG attribute metrics and limited site information, such as watershed area, gradient and ecoregion. After each panelist assigned a BCG level to a given sample, the panelist consensus was determined by calculating the median of all the panelists' BCG ratings. Participants were not allowed to view Station IDs or waterbody names when making BCG level assignments, as this might bias their assignments. A sample worksheet can be found in Appendix D.

In the final session of the workshop, panelists were asked to review decisions and notes, and identify the rules they used to make those decisions. Preliminary sets of decision rules were developed based on these calibration worksheets. These rules were later quantified and automated in an Excel spreadsheet and BCG level assignments were calculated for each sample. Panelists were asked to assess additional calibration worksheets during a series of follow-up homework assignments and webinars. During the webinars held after the workshop, panelists discussed samples that had the greatest differences between the BCG level assignments based on the model versus the panelists. Decision rules were then adjusted based on group consensus. Then the panelists worked individually to make BCG level assignments on additional samples to confirm the BCG models.

Table 3. Descriptions of the BCG attributes assigned to taxa for this exercise, plus a summary of how many taxa were assigned to each attribute group. This table is based on taxa that occurred in the Indiana fish BCG dataset.

BCG Attribute	Description	Number	Percent
I	Historically documented, sensitive, long-lived or regionally endemic taxa	2	1.2
II	Highly sensitive taxa, often occur in low abundance	19	11.3
III	Intermediate sensitive taxa	32	19.0
IV	Taxa of intermediate tolerance	80	47.6
V	Tolerant native taxa	14	8.3
VI	Non-native tolerant taxa	12	7.1
VIi	Non-native intolerant taxa	4	2.4
X	Indicating ecosystem connectivity (e.g., catadromous fish)	1	0.6
NA	No attribute assignment (insufficient information)	4	2.4
Totals		***168***	***100***

Table 4. Examples of Indiana fish by attribute group.

Ecological Attribute	Example Species
I Endemic, rare	Gilt Darter, Shovelnose Sturgeon
II Highly Sensitive	Tippecanoe Darter, Spotted Darter, Lamprey species, Gravel Chub, Greater Redhorse, Freckled Madtom, Mountain Madtom
III Intermediate Sensitive	Mottled and Banded Sculpin, Shorthead and Golden Redhorse, Brindled Madtom, Northern Hog Sucker, Banded Darter, Southern Redbelly and Longnose Dace
IV Intermediate Tolerant	Rainbow Darter, Johnny Darter, Orangethroat Darter, Sand Shiner, Longear Sunfish, Central Stoneroller, Bluegill
V Tolerant	Bluntnose Minnow, White Sucker, Creek Chub, Fathead Minnow, Green Sunfish, Largemouth Bass
VI Non-native	Common Carp, Grass Carp, Goldfish, Round Goby, Alewife, White Perch
VIi Non-native (intolerant)	Brown Trout, Chinook Salmon, Coho Salmon, Rainbow Trout
X Indicating ecosystem connectivity	American eel
NA Unassigned	Cyprinidae hybrid, Orangethroat-Rainbow Darter hybrid

Figure 10. The Flathead Catfish is an example of an Attribute IV (intermediate tolerant) taxa. This catfish was collected from the Wabash River near Logansport in 2008 (Stacey Sobat, IDEM).

3 DECISION RULES AND BCG MODELS

During the calibration exercise, panelists made BCG level assignments on 162 total samples from streams less than 1000 mi^2 in the 4 different regions (ECBP + IP, IRL, CCBP and SMNIDP; Figure 11), further stratified by stream size (< or ≥ 20 mi^2). In order to confirm the models, panelists made BCG level assignments on 40 additional samples from the 4 regions. For calibration of the large river fish BCG model, panelists made BCG level assignments on 25 large river samples that spanned the 4 regions. Five of the samples were collected from the Kankakee and Wabash Rivers by MBI and ORSANCO. These sites overlapped with sites that were also sampled by IDEM. In order to confirm the large river model, panelists made BCG level assignments on 9 additional samples[3]. BCG level assignments for all of the assessed samples are summarized in Appendix E.

3.1 Site Assignments and BCG Level Descriptions

The fish panelists assigned samples from streams less than 1000 mi^2 to BCG levels 2-6, and large river samples to BCG levels 2-5 (Table 5). Locations of the assessed sites are shown in Figure 11. No sites were assigned to BCG level 1, which is the least altered condition (Davies and Jackson 2006). Participants agreed that all sites in Indiana have some degree of disturbance, including legacy effects from agriculture and forestry from 100 to 200 years ago, so BCG level 2 samples represent the most natural waters in this exercise. Of the 202 total samples from streams less than 1000 mi^2 that were assessed, 5 were assigned to BCG level 2 and 18 were assigned to BCG level 6, which represents the most altered condition (Table 5). Of the 34 large river samples that were assessed, 5 were assigned to BCG level 2 (4 of which were located in the Eastern Corn Belt Plains) and none were assigned to BCG level 6 (Table 6). The greatest number of samples were assigned to BCG level 4 (Tables 5 & 6).

[3] One additional sample from the Scioto River in Ohio was also assessed, but this was not counted as a confirmation sample.

Table 5. Number of calibration and confirmation fish samples that were assessed in streams less than 1000 mi², organized by region and BCG level (group consensus).

Stream Class	BCG level	Calibration		Confirmation	
		< 20 mi²	≥ 20 mi²	< 20 mi²	≥ 20 mi²
Eastern Corn Belt Plains + Interior Plateau	2	0	4	0	1
	3	2	16	3	1
	4	12	21	1	1
	5	5	2	0	0
	6	1	4	1	1
	Totals	***20***	***47***	***5***	***4***
Interior River Lowlands	2	0	0	0	0
	3	0	3	0	2
	4	5	5	2	1
	5	2	6	2	1
	6	1	0	1	1
	Totals	***8***	***14***	***5***	***5***
Central Corn Belt Plains	2	0	0	0	0
	3	2	5	1	1
	4	12	8	4	2
	5	1	4	0	3
	6	4	2	0	0
	Totals	***19***	***19***	***5***	***6***
Southern Michigan/ Northern Indiana Drift Plains	2	0	0	0	0
	3	0	6	0	2
	4	7	12	2	1
	5	6	2	4	1
	6	2	0	0	0
	Totals	***15***	***20***	***6***	***4***

Table 6. Number of calibration and confirmation large river fish samples that were assessed, organized by BCG level (group consensus).

BCG level	Calibration	Confirmation
2	2	3
3	5	1
4	14	4
5	4	1
6	0	0
Totals	***25***	***9***

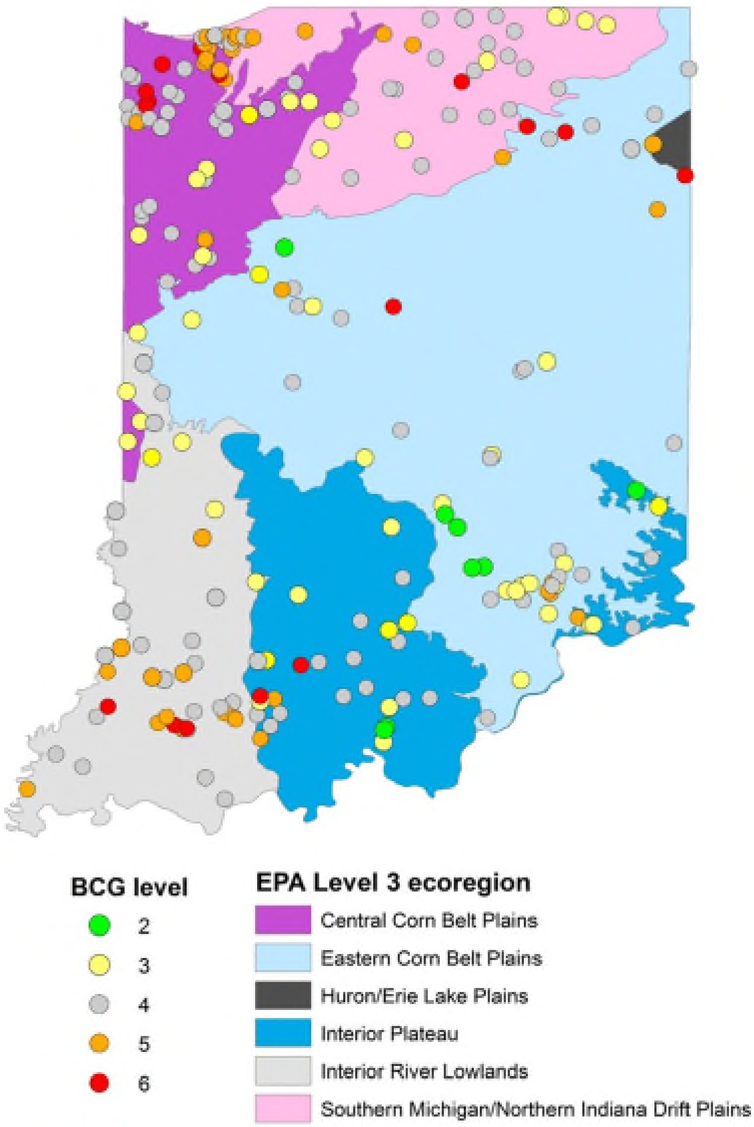


Figure 11. Locations of assessed fish samples, coded by panelist BCG level assignment (group median).

3.2 BCG Attribute Metrics

Examinations of taxonomic attributes among the BCG levels determined by the panel showed that several of the attributes are useful in distinguishing levels, and were used by the panel's biologists for decision criteria. In streams less than 1000 mi^2, the most important considerations are number of total native taxa, sensitive and connectivity-indicating taxa (Attribute I+II+III+X), and percent of tolerant and non-native (Attribute V+VI) taxa[4], individuals and biomass.

[4] The Attribute VI metric does not include the Attribute VIi taxa (Coho Salmon, Chinook Salmon, Rainbow Trout, Brook Trout, Brown Trout), which occur occasionally in the CCBP and SMNIDP datasets. These taxa are stocked and intolerant.

Individual taxonomic groupings, such as minnows, suckers, sunfish, darters, madtoms and sculpins are also considered important. All of the “highly desirable” attributes (I, II, III, and X) were grouped into a single metric because Attributes I, II and X occur very infrequently in the dataset and thus could not be used individually for rule development. In addition, a metric comprised of only the most sensitive and rare or endemic (attributes I,II) taxa was used to help discriminate between BCG levels 2 and 3. The metrics show relatively monotonic patterns, with percent tolerant and non-native individuals and biomass increasing and total native taxa and sensitive and connectivity-indicating taxa decreasing as the assigned BCG level (and level of anthropogenic disturbance) increases (Figure 12). The total native taxa metric discriminates well across all BCG levels. The sensitive taxa metric discriminates well across levels 2 to 4, while the percent tolerant and non-native metrics discriminates well between BCG levels 2 to 5.

Similar attributes are useful in distinguishing BCG levels for large river samples. The most important considerations are number of total native taxa, number and percent biomass of sensitive and connectivity-indicating taxa (Attribute I+II+III+X), and percent biomass of tolerant and non-native (Attribute V+VI) taxa. As with the smaller streams, individual taxonomic groupings (minnows, suckers, sunfish, darters, madtoms and sculpins) are considered important, and metrics show relatively monotonic patterns (Figure 12). The sensitive taxa metrics discriminate well across levels 2 to 4, while the percent biomass of tolerant and non-native taxa metric discriminates well between BCG levels 3 and 4. Figure 12 shows only ECBP+IP streams < 1000 mi^2; box plots for all metrics that were considered in this exercise can be found in Appendix F.

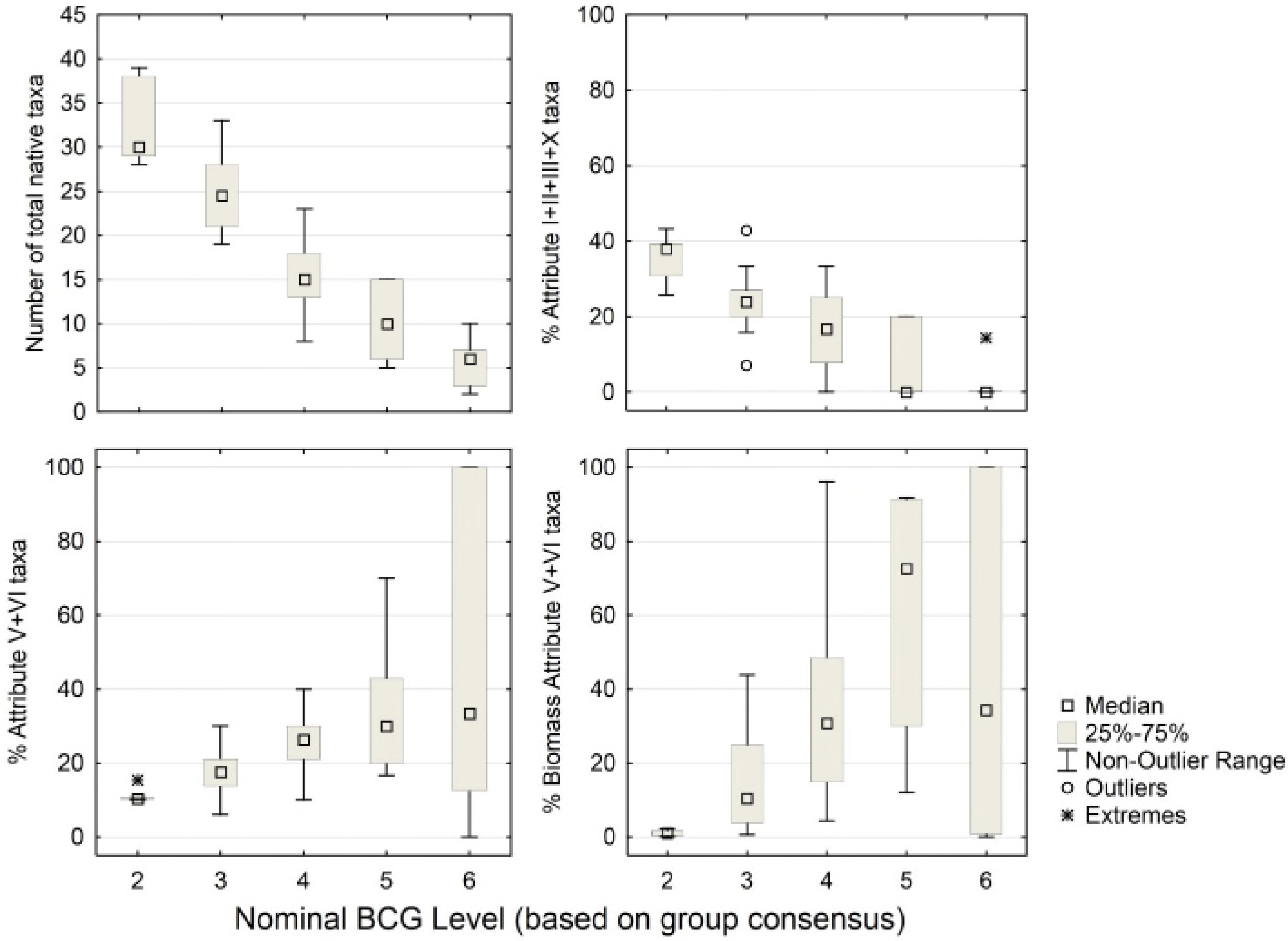


Figure 12. Box plots of total native taxa, percent sensitive (Attribute I+II+III+X) taxa, percent tolerant and non-native (Attribute V+VI) taxa and percent biomass tolerant and non-native (Attribute V+VI) taxa for assessed samples in the Eastern Corn Belt Plains + Interior Plateau region, grouped by nominal BCG level (group majority choice). Sample sizes for each BCG level are summarized in Table 5. Box plots for all metrics that were evaluated in each region can be found in Appendix F.

3.3 BCG Rule Development

At the spring 2015 workshop, the fish panel discussed and assessed approximately 70 samples from the ECBP+IP region, and came up with a set of preliminary decision rules. The initial rules were used as a starting point for the ECBP+IP quantitative model. Following initial development of the quantitative model, the panel reviewed the model and the rules, and assessed additional sites in the ECBP+IP as well as in other regions. For the other 3 regions (IRL, CCBP and SMNIDP) and large rivers, panelists assessed samples independently (as “homework”) and then discussed results as a group during a series of webinars. Some samples were then used in refinement/recalibration of the rules and quantitative models, and approximately 10 samples from each region were reserved for testing model performance on independent samples (referred to as “confirmation” samples).

The basis of the decision rules (Tables 7 & 8) is a general pattern of decreasing richness of sensitive taxa and increasing relative abundance and biomass of tolerant and non-native taxa as biological condition degrades (Figure 12). Rules for BCG level 2 have the highest thresholds for sensitive taxa and the lowest thresholds for tolerant organisms. They also have the highest threshold for total native taxa richness, which decreases as conditions degrade to BCG level 6 (which is depauperate) (Tables 7 & 8). For upper BCG levels (2 and 3), the panel used the distribution of species among 4 taxonomic fish groups as a basis for decision criteria (minnows, darters + sculpins + madtoms, suckers, and sunfishes). In the most natural streams (BCG level 2 and 3) at least 3 of the 4 fish groups were expected to be present, with sufficient species in each. As condition declined from BCG level 2 to 3, the number of species expected per group generally declined, and in BCG levels 4 to 6, there was no expectation for any particular taxonomic group (Tables 7 & 8). It should be noted that Table 7 includes Level 2 rules for the IRL, CCBP and SMNIDP regions, but these rules are preliminary (and should be interpreted with caution) because no BCG level 2 samples were assessed in these regions.

In streams <1000 mi^2, rules for BCG levels 2 to 4 include the percent most dominant Attribute V+VI taxon metric, which is the relative abundance of the (single) most abundant Attribute V or VI taxon (e.g., if green sunfish is the most abundant Attribute V or VI taxon in the sample, and there are 30 of them in a 100 total individual sample, the metric value equals 30%). The BCG level 2 rules require that the most abundant Attribute V or VI taxon comprises less than 25% of the individuals in a sample. Thresholds for % tolerant individuals, which vary slightly across regions, increase as conditions decline to BCG level 3 (≤ 35%) and level 4 (≤ 60%). The BCG level 2 and 3 rules also limit the percent biomass of tolerant and non-native taxa such as carp (e.g., Common and Grass Carp), while BCG level 4 rules limit the percent of Attribute V+VI individuals to ≤ 85%. The smallest streams (< 20 mi^2) have slightly higher thresholds for Attribute V+VI individuals since tolerant taxa such as Creek Chub and Bluntnose Minnow can naturally occur in relatively high abundances in headwater streams. Threshold differences between smaller (< 20 mi^2) and larger (20 to 1000 mi^2) streams also exist for most of the richness metrics, since, in general, the number of resident fish species increases with stream size up to the range of 100 mi^2 to 500 mi^2 drainage area, and then levels off or declines slightly (Karr et al. 1986, Yoder and Rankin 1995a). A similar relationship for fish species was evident in the Indiana BCG dataset (Figure 8).

In the large river BCG model, BCG level 2 rules require the presence of at least 26 total native taxa, at least 1 of which is highly sensitive (Attribute I+II) and 6 of which are sensitive and connectivity-indicating taxa (Attribute I+II+III+X). Non-native (Attribute VI) taxa such as Common Carp can be present in BCG level 2 large river samples, but only in very low numbers (less than 4 individuals). The large river model also requires that at least 40% of the biomass in BCG level 2 samples is comprised of sensitive and connectivity-indicating taxa (Attribute I+II+III+X); this threshold is relaxed to 15% in BCG level 3 samples. BCG Level 4 rules limit the percent of Attribute V+VI individuals to ≤ 45%. BCG level 4 has one set of alternate rules; these require either the presence of more than 3 sensitive taxa or at least 95 total individuals in the sample.

For all of the BCG models, there are also rules for external fish abnormalities (deformities, erosion, lesions and tumors – referred to as “DELT anomalies”). DELT anomalies are a wellestablished indicator of water quality and fish health (Karr 1986, Plumb 1994, Yoder and Rankin 1995b). Studies dating back to the 1960s have documented higher numbers or percentages of individuals with DELTs at sites affected by industrial or sewage discharges. At low percentages, DELTs can be a symptom of sub-chronic stress, while at higher levels, DELTs can be a sign of acute stress (see review by Sanders et al. 1999). For the Indiana fish BCG models, we attempted to develop quantitative DELT rules for each BCG level, using DELT metric thresholds from the Indiana fish Index of Biotic Integrity (IBI) as initial guidance. Ultimately we only included a quantitative DELT rule for BCG level 2, which requires that no individuals with DELTs occur in BCG level 2 samples. It was difficult to calibrate quantitative BCG rules for DELTs in BCG level 3 to 5 samples because DELTs occur infrequently and in limited numbers in the BCG dataset. For now, the IDEM fish experts decided to flag any BCG level 3 to 5 samples that have 2 or more individuals with DELTs for further evaluation, and will work on developing narrative guidance on how to adjust BCG outputs for the flagged samples. DELT anomalies are important indicators and should be cause for concern.

Table 7. BCG quantitative decision rules for fish assemblages. The numbers in parentheses represent the lower and upper bounds of the fuzzy sets (for more details, see Section 2.1.3). BCG level 2 rules in gray text are conceptual/untested (no BCG level 2 samples were identified in the CCBP, SMNDIP and IRL regions).

BCG Level 2	CCBP		SMNIDP		IRL		ECBP + IP	
	< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2
Number of total native taxa	≥ 23 (18-28)	≥ 25 (20-30)	≥ 23 (18-28)	≥ 25 (20-30)	≥ 23 (18-28)	≥ 25 (20-30)	≥ 23 (18-28)	≥ 25 (20-30)
Number of Attribute I+II taxa	≥ 1 (0-1)		≥ 1 (0-1)		≥ 1 (0-1)		≥ 1 (0-1)	
% Attribute I+II+III+X taxa	≥ 25% (20-30)		≥ 30% (25-35)		≥ 25% (20-30)		≥ 20% (15-25)	≥ 25% (20-30)
% Individuals - most dominant Attribute V or VI taxon	≤ 25% (20-30)		≤ 25% (20-30)		≤ 20% (15-25)		≤ 25% (20-30)	
% Biomass Attribute V+VI taxa	≤ 40% (35-45)		≤ 40% (35-45)		≤ 40% (35-45)		≤ 35% (30-40)	
% DELT anomalies	0%		0%		0%		0%	
Number of minnow taxa	≥ 5 (3-7)		≥ 5 (3-7)		≥ 5 (3-7)		> 6 (4-9)	
Number of darter + sculpin + madtom taxa	> 2 (1-4)		> 2 (1-4)		> 2 (1-4)		≥ 5 (3-7)	
Number of sucker taxa	≥ 2 (1-3)	≥ 3 (1-5)	≥ 2 (1-3)	≥ 3 (1-5)	≥ 2 (1-3)	≥ 3 (1-5)	≥ 2 (1-3)	≥ 3 (1-5)
Number of sunfish taxa	≥ 2 (1-3)	≥ 3 (1-5)	≥ 2 (1-3)	≥ 3 (1-5)	≥ 4 (2-6)	≥ 5 (3-7)	≥ 2 (1-3)	≥ 3 (1-5)
	Combination rule (applies to shaded cells) - model uses the best of 3 of 4		Combination rule (applies to shaded cells) - model uses the best of 3 of 4		Combination rule (applies to shaded cells) - model uses the best of 3 of 4		Combination rule (applies to shaded cells) - model uses the best of 3 of 4	

Table 7. continued…

BCG Level 3	CCBP		SMNIDP		IRL		ECBP + IP	
	< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2
Number of total native taxa	≥ 13 (8-18)	≥ 14 (9-19)	≥ 15 (10-20)	≥ 19 (14-24)	≥ 17 (12-22)	≥ 20 (15-25)	≥ 17 (12-22)	≥ 19 (14-24)
Number of total individuals	≥ 100 (95-105)		--		--		--	
% Attribute I+II+III+X taxa	> 7% (4-11)	≥ 15% (10-20)	≥ 20% (15-25)		≥ 10% (5-15)		≥ 10% (5-15)	≥ 15% (10-20)
% Individuals - most dominant Attribute V or VI taxon	≤ 35% (30-40)		≤ 40% (35-45)		≤ 35% (30-40)		≤ 35% (30-40)	
% Attribute V+VI taxa	≤ 35% (30-40)	≤ 30% (25-35)	≤ 30% (25-35)		≤ 25% (20-30)		≤ 35% (30-40)	≤ 25% (20-30)
% Biomass Attribute V+VI taxa	≤ 80% (75-85)		≤ 80% (75-85)		≤ 50% (45-55)		≤ 50% (45-55)	
Number of individuals with DELTs	≥ 2, flag for further evaluation		≥ 2, flag for further evaluation		≥ 2, flag for further evaluation		≥ 2, flag for further evaluation	
Number of minnow taxa	≥ 3 (1-5)	≥ 4 (2-6)	≥ 3 (1-5)	≥ 4 (2-6)	≥ 3 (1-5)	≥ 4 (2-6)	≥ 3 (1-5)	≥ 4 (2-6)
Number of darter + sculpin + madtom taxa	≥ 1 (0-1)		≥ 1 (0-1)		≥ 1 (0-1)		≥ 2 (1-3)	≥ 3 (1-5)
Number of sucker taxa	≥ 1 (0-1)	≥ 2 (1-3)	≥ 1 (0-1)	≥ 2 (1-3)	≥ 1 (0-1)	≥ 2 (1-3)	≥ 1 (0-1)	≥ 2 (1-3)
Number of sunfish taxa	≥ 1 (0-1)	≥ 2 (1-3)	≥ 1 (0-1)	≥ 2 (1-3)	≥ 3 (1-5)	≥ 4 (2-6)	≥ 1 (0-1)	≥ 2 (1-3)
	Combination rule (applies to shaded cells) - model uses the best 3 of 4		Combination rule (applies to shaded cells) - model uses the best 3 of 4		Combination rule (applies to shaded cells) - model uses the best 3 of 4		Combination rule (applies to shaded cells) - model uses the best 3 of 4	

Table 7. continued…

BCG Level 4	**CCBP**		**SMNIDP**		**IRL**		**ECBP + IP**	
	< 20 mi2	**≥ 20 mi2**	**< 20 mi2**	**≥ 20 mi2**	**< 20 mi2**	**≥ 20 mi2**	**< 20 mi2**	**≥ 20 mi2**
Number of total native taxa	≥ 6 (3-9)	> 7 (5-10)	> 5 (3-8)	> 7 (5-10)	≥ 6 (4-8)	≥ 13 (8-18)	> 7 (5-10)	≥ 9 (4-14)
Number of total individuals	≥ 20 (15-25)	≥ 35 (30-40)	≥ 30 (25-35)	≥ 35 (30-40)	≥ 45 (40-50)	≥ 50 (45-55)	≥ 35 (30-40)	
% Attribute I+II+III+IV+X taxa	≥ 35% (30-40)	≥ 40% (35-45)	≥ 30% (25-35)	≥ 40% (35-45)	≥ 45% (40-50)		≥ 50% (45-55)	
% Individuals - most dominant Attribute V or VI taxon	≤ 55% (50-60)	≤ 60% (55-65)	≤ 55% (50-60)		≤ 50% (45-55)		≤ 50% (45-55)	≤ 45% (40-50)
% Attribute V+VI individuals	≤ 80% (75-85)	≤ 70% (65-75)	≤ 85% (80-90)	≤ 75% (70-80)	≤ 80% (75-85)	≤ 70% (65-75)	≤ 70% (65-75)	
Number of individuals with DELTs	≥ 2, flag for further evaluation		≥ 2, flag for further evaluation		≥ 2, flag for further evaluation		≥ 2, flag for further evaluation	

BCG Level 5	**CCBP**		**SMNIDP**		**IRL**		**ECBP + IP**	
	< 20 mi2	**≥ 20 mi2**	**< 20 mi2**	**≥ 20 mi2**	**< 20 mi2**	**≥ 20 mi2**	**< 20 mi2**	**≥ 20 mi2**
Number of total native taxa	≥ 3 (1-5)	> 3 (2-5)	> 2 (1-4)	> 3 (2-5)	> 2 (1-4)	> 3 (2-5)	≥ 4 (2-6)	> 6 (4-9)
Number of total individuals	≥ 15 (10-20)	≥ 20 (15-25)	≥ 10 (5-15)	≥ 15 (10-20)	> 10 (6-15)	≥ 15 (10-20)	≥ 15 (10-20)	≥ 20 (15-25)
% Attribute VI individuals	≤ 60% (55-65)		--		--		--	
Number of individuals with DELTs	≥ 2, flag for further evaluation		≥ 2, flag for further evaluation		≥ 2, flag for further evaluation		≥ 2, flag for further evaluation	

Table 8. BCG quantitative decision rules for large river fish assemblages. The numbers in parentheses represent the lower and upper bounds of the fuzzy sets (for more details, see Section 2.1.3).

<table>
<tr><th>BCG Level 2</th><th colspan="2">Large Rivers (all regions)</th><th></th></tr>
<tr><td>Number of total native taxa</td><td colspan="2">≥ 26 (21-31)</td><td></td></tr>
<tr><td>Number of Attribute I+II taxa</td><td colspan="2">≥ 1 (0-2)</td><td></td></tr>
<tr><td>Number of Attribute I+II+III+X taxa</td><td colspan="2">≥ 6 (3-9)</td><td></td></tr>
<tr><td>% Biomass Attribute I+II+III+X taxa</td><td colspan="2">≥ 40% (35-45)</td><td></td></tr>
<tr><td>Number of Attribute VI individuals</td><td colspan="2">< 4 (0-7)</td><td></td></tr>
<tr><td>% DELT anomalies</td><td colspan="2">0% (0-1)</td><td></td></tr>
<tr><td>Number of minnow taxa</td><td colspan="2">≥ 2 (1-3)</td><td rowspan="4">Combination rule (applies to shaded cells) - model uses the best of 3 of 4</td></tr>
<tr><td>Number of darter + sculpin + madtom taxa</td><td colspan="2">≥ 3 (1-5)</td></tr>
<tr><td>Number of sucker taxa</td><td colspan="2">> 4 (3-6)</td></tr>
<tr><td>Number of sunfish taxa</td><td colspan="2">> 3 (2-5)</td></tr>
<tr><th>BCG Level 3</th><th colspan="2">Large Rivers (all regions)</th><th></th></tr>
<tr><td>Number of total native taxa</td><td colspan="2">≥ 23 (18-28)</td><td></td></tr>
<tr><td>Number of Attribute I+II+III+X taxa</td><td colspan="2">> 2 (1-4)</td><td></td></tr>
<tr><td>% Biomass Attribute I+II+III+X taxa</td><td colspan="2">≥ 15% (10-20)</td><td></td></tr>
<tr><td>% Biomass Attribute V+VI taxa</td><td colspan="2">≤ 45% (40-50)</td><td></td></tr>
<tr><td>Number of individuals with DELTs</td><td colspan="2">≥ 2, flag for further evaluation</td><td></td></tr>
<tr><td>Number of minnow taxa</td><td colspan="2">≥ 2 (1-3)</td><td rowspan="4">Combination rule (applies to shaded cells) - model uses the best of 3 of 4</td></tr>
<tr><td>Number of darter + sculpin + madtom taxa</td><td colspan="2">≥ 2 (1-3)</td></tr>
<tr><td>Number of sucker taxa</td><td colspan="2">≥ 4 (2-6)</td></tr>
<tr><td>Number of sunfish taxa</td><td colspan="2">≥ 2 (1-3)</td></tr>
<tr><th rowspan="2">BCG Level 4</th><th colspan="2">Large Rivers (all regions)</th><th></th></tr>
<tr><th>alt 1</th><th>alt 2</th><th></th></tr>
<tr><td>Number of total native taxa</td><td colspan="2">≥ 16 (11-21)</td><td></td></tr>
<tr><td>Number of total individuals</td><td>--</td><td>≥ 95 (90-100)</td><td></td></tr>
<tr><td>Number of Attribute I+II+III+X taxa</td><td>> 3 (2-5)</td><td>--</td><td></td></tr>
<tr><td>% Attribute V+VI individuals</td><td colspan="2">≤ 45% (40-50)</td><td></td></tr>
<tr><td>Number of individuals with DELTs</td><td colspan="2">≥ 2, flag for further evaluation</td><td></td></tr>
<tr><th>BCG Level 5</th><th colspan="2">Large Rivers (all regions)</th><th></th></tr>
<tr><td>Number of total native taxa</td><td colspan="2">≥ 8 (5-11)</td><td></td></tr>
<tr><td>Number of total individuals</td><td colspan="2">≥ 20 (15-25)</td><td></td></tr>
<tr><td>Number of individuals with DELTs</td><td colspan="2">≥ 2, flag for further evaluation</td><td></td></tr>
</table>

3.4 Panel variability and model performance

Panel variability

Panelists showed a fairly high level of agreement in their decisions. The calibration sites in the ECBP+IP region were discussed and rated as a group during the spring 2015 workshop, so that all panelists could see each other's decisions. The other calibration samples were rated independently by the panelists (as homework), so that they did not see each other's ratings. However they did have opportunities to discuss the ratings as a group and change ratings (if desired) during follow-up webinars and email exchanges. During the group discussions, there was some convergence as panelists made arguments for one BCG level or another. Panelists were allowed to rate sites as a single BCG number, and were allowed to apply a plus (+) or minus (-) to the level indicating somewhat better or worse condition, respectively (much as school letter grades can be modified, e.g., B+) (see Appendix E, Figure E1). This effectively meant that the panelists were rating sites in increments of 1/3 BCG level. Figure 13 shows the distribution of individual panelist scores compared to the group median for each site. For the calibration sites, 82% of individual assessments were within 1/3 BCG level of the group median, and 96% were within 2/3 BCG level (Figure 13). Results were similar for the confirmation samples (which were also rated independently): 78% of ratings were within 1/3 BCG level of the panel median, and 94% were within 2/3 BCG level (Figure 13). Finally, there was no clear pattern in the amount of convergence/nonconvergence among BCG level decisions (Figure 14). During the calibration round, the best (BCG level 2) and worst (BCG level 6) samples had higher mean percentages of exact matches (Figure 14).

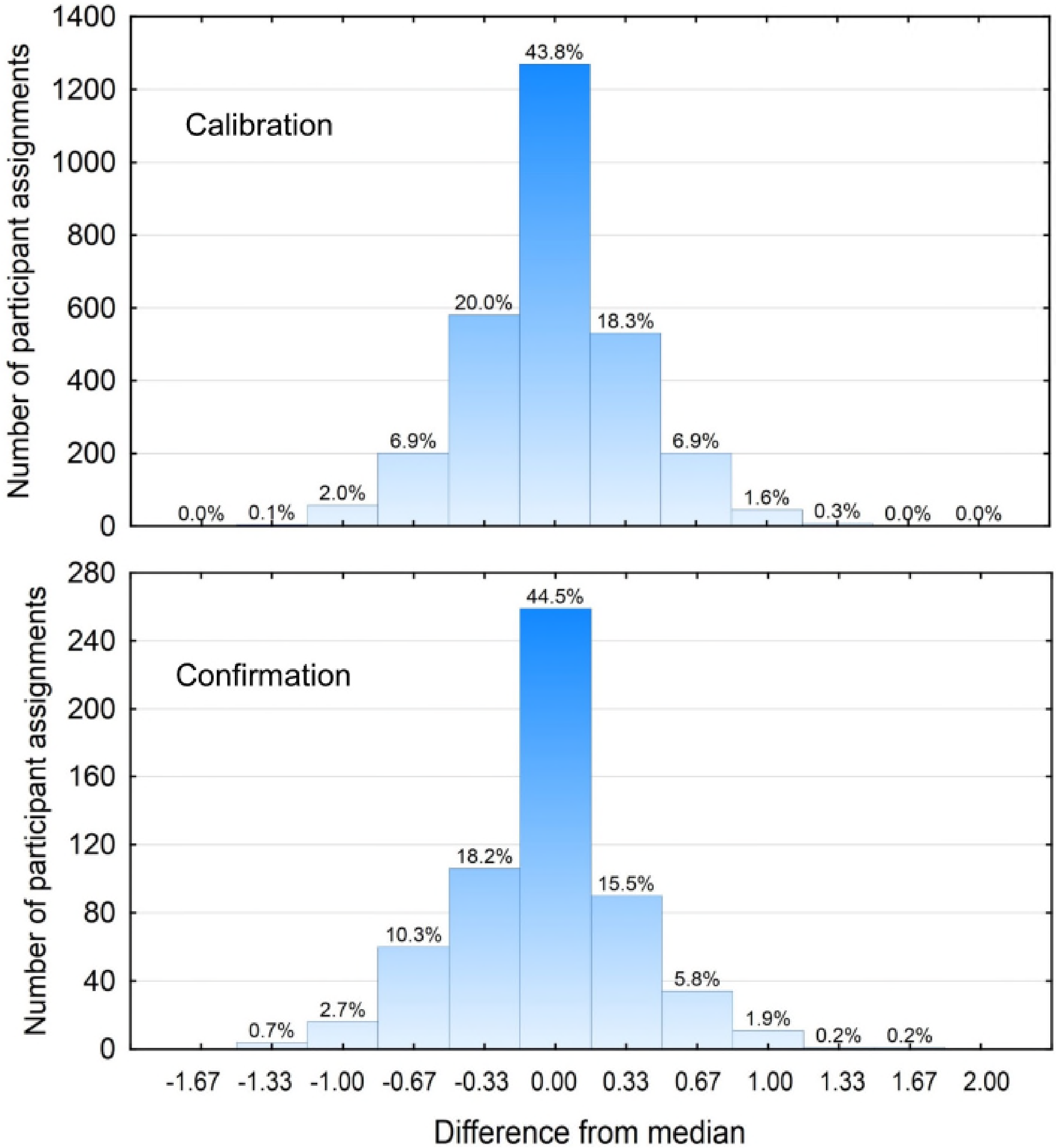


Figure 13. Distribution of fish panelist BCG level assignments expressed as difference from the group median. Calibration (top) and confirmation (bottom) samples from the Indiana BCG fish dataset (sample size for the calibration dataset = 187 sample size for the confirmation dataset = 49).

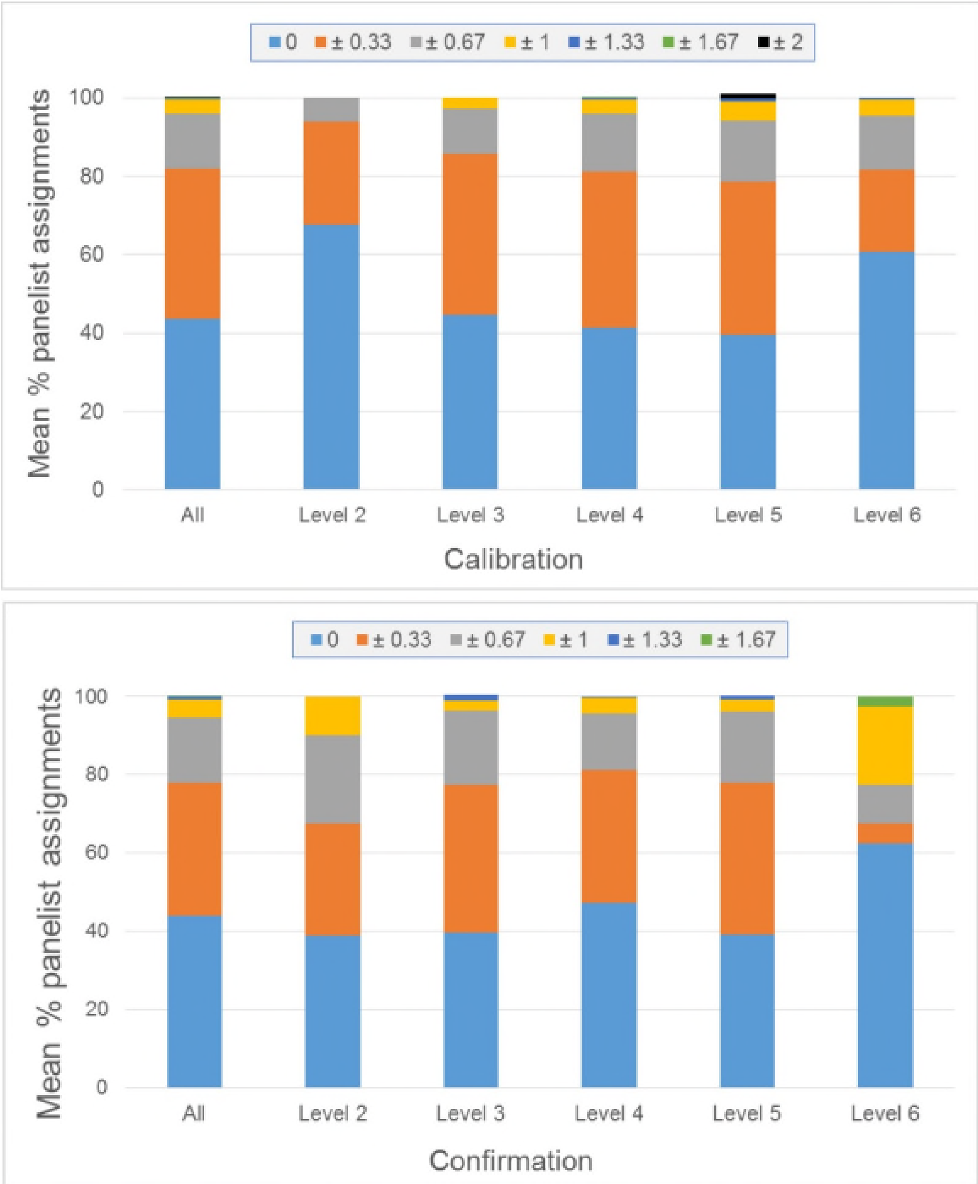


Figure 14. Distribution of panelist BCG level assignments as differences from the group median, by BCG level. Results are based on calibration (top) and confirmation (bottom) samples from the Indiana fish BCG dataset. Sample sizes are shown in Tables 5 & 6.

Quantitative Model Performance

To evaluate the performance of the calibration and confirmation datasets, we assessed the number of samples where the BCG decision model's nominal level exactly matched the panel's median ("exact match") and the number of samples where the model predicted a BCG level that differed from the median expert opinion ("mismatch" samples). Then, for the mismatched samples, we examined how large the differences were between the BCG level assignments, and also whether there was a bias (e.g., did the BCG model consistently rate samples better or worse than the panelists).

The quantitative BCG model output is in terms of relative membership of a site among BCG levels, from 0 to 100%, where memberships of all levels must sum to 100%. Most often, model output was 100% assigned to a single level, but it could also yield ties between adjacent levels, or a majority assigned to one level over one or more others. As with the quantitative model, panelists could split among BCG levels. To estimate concurrence between the quantitative model and the panel, we assigned scores as “clear majority” or “ties and near-ties” based on the panelists’ votes and the model membership outcomes. We assigned ties and near-ties where either the model or the panel were divided:

- **BCG model ties**, where there is nearly equal membership in 2 BCG levels (the difference between the primary and secondary memberships is less than 0.2; e.g., membership of 0.54 in BCG level 2 and membership of 0.46 in BCG level 3).

- **Panelist ties**, where a single vote could have flipped the decision (e.g., 4-4, or 5-4 decisions).

If the BCG model assigned a tie, and that tie did not match with the panelist consensus, we considered this to be a difference of half a BCG level (e.g., if the BCG model assignment was a BCG level 2/3 tie and panelist consensus was a BCG level 2, the model was considered to be ‘off by a half BCG level’; or more specifically, the model rating was a ½ BCG level “worse” than the panelists’ consensus). The BCG model was also considered to differ by a half level if the panelists assigned a tie and the BCG model did not. To avoid cutting the differences too finely, we only considered mismatches by units of half a BCG level as follows: match (both panel and model a clear majority for the same level or the same tie); up to ½ level (panel and model mismatch by no more than ½ BCG level); up to 1 level (panel and model mismatch ½ but no more than 1 BCG level); and so on.

Model performance is summarized in Table 9, showing number and percent of model assessments compared to panel assessments. The panel did not consider a half-level mismatch with their consensus to be a meaningfully different assessment, and a half level was similar to the spread in ratings among panel members. Accordingly, the panel was unwilling to adjust ratings or to modify rules for small mismatches. On average, the quantitative models were 98% accurate in replicating the panel assessments within one-half BCG level for the calibration data sets, and 94% accurate for the confirmation data. There was no mismatch greater than 1 BCG level. For the large river dataset, the subset of calibration samples that were collected by MBI and ORSANCO from the Kankakee and Wabash Rivers were compared to BCG assessment results from overlapping IDEM sites. Panelist median BCG ratings for these samples matched across the paired samples, despite the differences in each agency’s collection methods. If the IDEM large river BCG model is applied to additional ORSANCO/MBI samples, results should be interpreted with caution due to the small sample size of the test population.

In our opinion, the distribution of errors (mismatches) combined with the panel consensus on the degree of error that is biologically meaningful, is the best statistical estimate of goodness-of-fit that we know at this time. Other measures do not yield interpretable results, for example, Cohen's Kappa (e.g., Agresti 2013) estimates p-values compared to random independence and the resultant p-values are so small (10^{-100} and smaller) as to be meaningless; or Wilcoxon's Signed rank (W) test estimates difference in the means (measurement of bias of the paired estimates).

Table 9. Performance of BCG quantitative fish models for calibration and confirmation datasets, by Indiana ecosystem group. "Better" and "worse" indicate model assessment of stream condition compared to panel (e.g., "better" if model assessed BCG level 2, but panel assessed BCG level 3, and so forth).

Region	Dataset	Unit	Difference					
			Model 1 level better	Model 1/2 level better	Exact match	Model 1/2 level worse	Model 1 level worse	*Total*
Eastern Corn Belt Plains + Interior Plateau	Calibrate	Number	1	4	60	2		***67***
		Percent	1.5%	6.0%	89.6%	3.0%		***100%***
	Confirm	Number			9			***9***
		Percent			100%			***100%***
Interior River Lowlands	Calibrate	Number		1	19	2		***22***
		Percent		4.5%	86.4%	9.1%		***100%***
	Confirm	Number		1	8		1	***10***
		Percent		10.0%	80.0%		10.0%	***100%***
Central Corn Belt Plains	Calibrate	Number	1	2	32	3		***38***
		Percent	2.6%	5.3%	84.2%	7.9%		***100%***
	Confirm	Number			9	1	1	***11***
		Percent			81.8%	9.1%	9.1%	***100.0%***
Southern Michigan/ Northern Indiana Drift Plains	Calibrate	Number		2	31	1	1	***35***
		Percent		5.7%	88.6%	2.9%	2.9%	***100%***
	Confirm	Number	1	1	8			***10***
		Percent	10.0%	10.0%	80.0%			***100%***
Large Rivers	Calibrate	Number	1		23	1		**25**
		Percent	4.0%		92.0%	4.0%		**100%**
	Confirm	Number			8	1		**9**
		Percent			88.9%	11.1%		**100%**
Total	***Calibrate***	***Number***	***3***	***9***	***165***	***9***	***1***	***187***
		Percent	***1.6%***	***4.8%***	***88.3%***	***4.8%***	***0.5%***	***100%***
	Confirm	***Number***	***1***	***2***	***42***	***2***	***2***	***49***
		Percent	***2.0%***	***4.1%***	***85.7%***	***4.1%***	***4.1%***	***100.0%***

3.5 Description of assemblages in each BCG level

When panelists assess samples, they often associate particular taxa (and abundances of these taxa) with certain BCG levels. In Table 10, we provide narrative descriptions of each of the BCG levels that were assessed during this exercise (modified after Jackson et al. 2013), as well as lists of fish taxa that were commonly found in samples from each BCG level.

Table 10. Description of fish assemblages in each assessed BCG level for Indiana streams and large rivers. Definitions are modified after Davies and Jackson (2006).

BCG level 1	**Definition:** Natural or native condition - *native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability*
	Narrative from expert panel: There are no BCG level 1 sites within Indiana. All sites have some degree of disturbance, including legacy effects from agriculture and forestry from 100 to 200 years ago. Conceptually, BCG level 1 sites would have strictly native taxa for all assemblages evaluated (fish, salamander, benthic macroinvertebrates), some endemic species, and evidence of connectivity in the form of migratory fish.
	Fish: Examples of endemic species that might be present (depending on the size of the stream) include: Gilt Darter, Variegate Darter, Redside Dace, and Pallid Shiner. Historically, Freshwater Eel were indicators of connectivity, but due to the number of dams now, the eels are likely limited to remnant populations only
BCG level 2	**Definition:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function - *virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability*
	Narrative from expert panel: Overall taxa richness and density is as naturally occurs (watershed size is a consideration). These sites have excellent water quality and support habitat critical for native taxa. They have many highly sensitive taxa and relatively high richness and abundance of intermediate sensitive taxa. Many of these taxa are characterized by having limited dispersal capabilities or are habitat specialists. If tolerant taxa are present, they occur in low numbers. There is connectivity between the mainstem, associated wetlands and headwater streams.
	Fish: Highly sensitive (Attribute II) and intermediate sensitive (Attribute III) taxa such as Tippecanoe Darter, Spotted Darter, Lamprey species, Gravel Chub, and Madtom species are present. For large rivers, Shovelnose Sturgeon, Goldeye, Paddlefish are present.

Table 10 continued…

BCG level 3	**Definition:** Evident changes in structure of the biotic community and minimal changes in ecosystem function - *Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system*
	Narrative from expert panel: Generally considered to be in good condition. Similar to BCG level 2 assemblage except the proportion of total richness represented by rare, specialist and vulnerable taxa is reduced. Intermediate sensitive taxa have relatively high richness and abundance. Taxa with intermediate tolerance may increase but generally comprise less than half total richness and abundance. Tolerant taxa are somewhat more common but still have low abundance. Taxa with slightly broader temperature or sediment tolerance may be favored.
	Fish: Intermediate sensitive (Attribute III) taxa such as the Redhorse species and Sculpins (Mottled or Banded) are common or abundant. Taxa of intermediate tolerance (Attribute IV) such as Central Stoneroller, Longear Sunfish, and Orangethroat and Rainbow Darters are present in greater numbers than in BCG level 2 samples. Some tolerant (Attribute V) taxa such as Bluntnose Minnow and White Suckers may be present, but highly tolerant taxa are absent. Pioneering species such as Blacknose Dace, Creek Chubs, and White Suckers may be naturally common in smaller streams.
BCG level 4	**Definition:** Moderate changes in structure of the biotic community and minimal changes in ecosystem function - *Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*
	Narrative from expert panel: Sensitive species and individuals are still present but in reduced numbers (e.g., approximately 10 – 30% of the community rather than 50% found in level 3 streams). The persistence of some sensitive species indicates that the original ecosystem function is still maintained albeit at a reduced level. Densities and richness of intermediate tolerance taxa have increased compared to BCG level 3 samples.
	Fish: 2 or 3 intermediate sensitive taxa may be present but occur in very low numbers (e.g., Redhorse species, Sculpin species, Mimic Shiner, or River Chub). Taxa of intermediate tolerance (Attribute IV) such as Rainbow Darter, Sand Shiner, Longear Sunfish, and Central Stoneroller are common, as well as tolerant taxa like Largemouth Bass, Blacknose Dace, and Bluntnose Minnow.

Table 10 continued…

BCG level 5	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function - *Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative from expert panel: Overall abundance of all taxa reduced. Sensitive species may be present but their functional role is negligible within the system. Those sensitive taxa remaining are highly ubiquitous within the region and have very good dispersal capabilities. The most abundant organisms are typically tolerant or have intermediate tolerance, and there may be relatively high diversity within the tolerant organisms. Most representatives are opportunistic or pollution tolerant species.
	Fish: Facultative species reduced or absent. Tolerant taxa like Green Sunfish, Largemouth Bass, Blacknose Dace, and Bluntnose Minnow are common. Blacknose Dace, Creek Chubs and White Suckers may dominate.
BCG level 6	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function - *Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative from expert panel: Heavily degraded from urbanization and/or industrialization. Can range from having no aquatic life at all or harbor a severely depauperate community composed entirely of highly tolerant or tolerant invasive species adapted to hypoxia, extreme sedimentation and temperatures, or other toxic chemical conditions.
	Fish: Fish are low in abundance or absent, represented mainly by Yellow Bullhead, Green Sunfish, Bluntnose Minnow, Creek Chub, or Common Carp.

4 DISCUSSION

The conceptual model of the BCG was derived from widespread empirical experience of working aquatic ecologists from across the country (Davies and Jackson 2006). The calibration process of the index is simultaneously quantitative, empirical, and conceptual. The BCG is calibrated using a data set, but also requires ecological considerations with wide expert agreement from biologists familiar with the resources. The result is intended to be more general than a regression analysis of biological response to an anthropogenic stressor gradient. The BCG uses attributes (attributes I to VI) that are intended to apply in all regions. However, specifics of the attributes (taxon membership, attribute levels indicating natural, moderate, highly altered, etc.) do vary across regions and stream types, but the attributes themselves and their importance are consistent. The BCG requires descriptions of the levels from pristine to degraded. Documentation of the rationale for making BCG level determinations provides the foundation for building robust quantitative models and ensures that future information and discoveries can be related back to the baseline level descriptions. BCG levels are intended to be universal, so that a BCG level 3 assessment means the same in Indiana as it does in, say, Illinois.

The BCG is not conceptually tied to the population of available sites for reference condition. Although least disturbed sites may be used as a practical ground truth, it is recognized at the outset that these sites are typically less than pristine, and may be a lower level (e.g., 2, 3, 4). The levels of the BCG are biologically recognizable stages in the condition of stream waterbodies. As such, they can form a biological basis for criteria and regulation of a state's waterbodies. Thresholds of narrative biocriteria in some states may be relatively low (e.g., level 4-level 5), and fail to protect outstanding condition waters (levels 1 and 2), or even good condition waters (level 3). Low protection levels are often the result of low levels of rigor in monitoring and assessment (U.S. EPA 2013). Thus, biocriteria set at a lower BCG level will allow incremental degradation of waterbodies to the regulatory level.

To develop the fuzzy decision analysis system, we had to have a set of rules to which we could apply fuzzy logic. This may be the greatest single strength of the fuzzy model approach - development of a set of transparent rules that can, in principle, be followed by anyone in making a decision on a site. The experts can describe the classes of the BCG in a very general way, but without the specific rules and their combination, there is no way to replicate their decisions or to effectively modify rules with new knowledge. The quantitative rules are transparent and can be followed by anyone with basic knowledge of aquatic organisms. Although it may seem exotic to those not familiar with the approach, the fuzzy model rules are fully laid out and are not hidden in a statistical model or in artificial machine learning.

Aquatic biologists from the IDEM, IDNR, City of Elkhart, Muncie Sanitary District, Eastern Kentucky University, Ball State University, USGS, NPS and MBI partnered to develop a common assessment system based on the BCG for fish assemblages in Indiana streams and large rivers. This was a collective exercise among regional biologists to develop consensus on assessments of samples. We elicited the rules that the biologists used to assess the samples, and developed a set of quantitative decision criteria rules for assigning samples to BCG levels. There was fairly high agreement among the biologists performing the assessments (Figure 13), and very high concordance between the expert assessment and the quantitative BCG model (Table 9). The concordance increases our confidence in the consensus professional judgment to assess sites, and in the quantitative model to replicate that judgment.

As new data are collected, IDEM and partners will be able to generate BCG model outputs using an Access application that is being developed for this project. The upper extreme of the BCG gradient, BCG level 2, was not well represented in the data set, and any sites identified by routine application of the quantitative model as BCG level 2 should also be examined by professional biologists. There were no rules identified for BCG level 1, which is clearly an area for further investigation.

Moving ahead, the IDEM could potentially use the BCG models to supplement and enhance the IBI measures that they currently use to assess stream health. If the BCG models are utilized, users should consider the limitations of the models. Results from the fish BCG models should be interpreted with caution and checked using professional assessment if they are applied to small headwater streams with drainage areas of 5 square miles or less. These smaller streams can be difficult to assess because they support fewer fish taxa and are more prone to intermittency (particularly in southern Indiana), and limited numbers of sites in this size class were assessed during the calibration and confirmation rounds. BCG model outputs for cool water streams in northern Indiana (some of which are direct tributaries to Lake Michigan) should also be interpreted with caution because cool water streams support unique assemblages, and only a limited number of cool water sites were assessed during the BCG exercise. Samples should also be checked using professional assessment if they are not collected with IDEM's normal gear or protocols (see Appendix A), and if samples are collected outside of IDEM's normal sampling period.

The BCG can be an effective tool for communicating resource condition to the public and for informing management decisions to protect or remediate water resources. It can allow for practical and operational implementation of multiple aquatic life uses in a state's water quality criteria and standards. For example, several sites in the ECBP + IP region were assigned to BCG level 2, which, based on participants' input, represent the present-day most natural waters in Indiana. Development of quantitative BCG models provides a technical tool for identifying and potentially protecting Indiana's highest quality streams, as well as developing realistic restoration goals for waters impacted by legacy activities, such as ditching, impoundments, and urban and agricultural land use.

5 LITERATURE CITED

Agresti, A. 2013. Categorical Data Analysis. 3rd Edition. John Wiley and Sons, New York.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA/841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Borja, A., Franco, J., Muxika, I., 2004b. The Biotic Indices and the Water Framework Directive: the required consensus in the new benthic monitoring tools. Marine Pollution Bulletin 48 (3–4), 405–408

Castella, E. and M.C.D. Speight. 1996. Knowledge representation using fuzzy coded variables: an example based on the use of Syrphidae (Insecta, Diptera) in the assessment of riverine wetlands. Ecological Modelling 85:13-25.

Davies, S. B., and S. K. Jackson. 2006. The Biological Condition Gradient: A descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16(4):1251–1266.

Demicco, R.V. and G.J. Klir. 2004. Fuzzy Logic in Geology. Elsevier Academic Press, San Diego, CA.

Droesen, W.J. 1996. Formalisation of ecohydrological expert knowledge applying fuzzy techniques. Ecological Modelling 85:75-81.

Ibelings, B.W., M Vonk, H.F.J. Los, D.T. Van Der Molen, and W.M. Mooij. 2003. Fuzzy modeling of Cyanobacterial surface waterblooms: validation with NOAA-AVHRR satellite images. Ecological Applications 13:1456-1472.

Jackson, S., Pond, G. and J. Gerritsen. 2013. Biological Condition Gradient: A headwater steam catchment in the Northern Piedmont region, Montgomery County, Maryland. Technical Expert Workshop Report.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55- 68.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5.

Karr, J.R. and E.W. Chu. 1999. Restoring Life. In Running Waters: Better Biological Monitoring. Island Press, Washington, DC.

Karr, J.R. 2000. Health, integrity, and biological assessment: The importance of whole things. In Ecological Integrity: Integrating Environment, Conservation, and Health, D. Pimentel, L. Westra, and R. F. Noss (eds.), pp. 209–226. Island Press, Washington, DC.

Klir, G.J. 2004. Fuzzy Logic: A Specialized Tutorial. In Fuzzy Logic in Geology, in R.V. Demicco and G.J. Klir (eds.), pp. 11-61. Elsevier Academic Press, San Diego, CA.

Kopf, R.K., C.M. Finlayson, P. Humphries, N.C. Sims, and S. Hladyz. 2015. Anthropocene baselines: Assessing change and managing biodiversity in human-dominated aquatic ecosystems. Bioscience. 65(8): 798-811 (August 2015).

Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers 77(1): 118-125.

Plumb, J.A. 1994. Health Maintenance of Cultured Fishes: Principal Microbial Diseases. CRC Press, Boca Raton, FL.

Sanders, R.E., Miltner, R.J., Yoder, C.O. and E.T. Rankin. 1999. The Use of External Deformities, Erosion, Lesions, and Tumors (DELT Anomalies) in Fish Assemblages for Characterizing Aquatic Resources: A Case Study of Seven Ohio Streams. In: T.P Simon (ed.) Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, pp. 225-246.

Simpson, J.C and R.H. Norris. 2000. Biological assessment of river quality: development of AusRivAS models and outputs. In Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques. J.F. Wright, D.W. Sutcliffe and M.T. Furse (eds.), pp. 125-142. Freshwater Biological Association, Ambleside, UK.

Steedman, R.J. 1994. Ecosystem health as a management goal. Journal of the North American Benthological Society. 13(4):605–610

Tewes, R., Emery, E. Thomas, J., Yoder, C.O., Rankin, E.T. and L.E. Hersha. Nd. Evaluation and Development of Large River Biological Assessment Methods and Standardized Protocols for Region V -Final Report for 104(b) Boat Electrofishing Methods Comparison Study.

USEPA (US Environmental Protection Agency). 2013. Biological Assessment Program Review: Assessing Level of Technical Rigor to Support Water Quality Management. Office of Science and Technology, Washington, DC; EPA 820-R-13-001.

USEPA (US Environmental Protection Agency). 2016. A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems. Office of Water, Washington DC. EPA 842-R-16-001.

Weisberg, S.B., B. Thompson, J.A. Ranasinghe, D.E. Montagne, D.B. Cadien, D.M. Dauer, D. Diener, J. Oliver, D.J. Reish, R.G. Velarde, and J.Q. Word. 2008. The level of agreement among experts applying best professional judgment to assess the condition of benthic infaunal communities. *Ecological Indicators* 8:389–394.

Wolock, D. 2003. Base-flow index grid for the conterminous United States [web page]. Available online: https://catalog.data.gov/dataset/base-flow-index-grid-for-the-conterminous-united-states

Wright, J.F. 2000. An introduction to RIVPACS. In Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques. J.F. Wright, D.W. Sutcliffe and M.T. Furse (eds.), pp. 1-24. Freshwater Biological Association, Ambleside, UK.

Yoder, C.O., and E.T. Rankin. 1995a. Biological criteria development and implementation in Ohio. Chapter 9 in W.S. Davis and T.P Simon eds. Biological Assessment and Criteria. Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O., and E.T. Rankin, 1995b. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data. In: W.S. Davis and T.S. Simon (eds.) Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making, Lewis Publishers, Boca Raton, FL. pp. 263-286.

Appendix A

IDEM Electrofishing Methodologies

Table A1. IDEM's Electrofishing Sampling Methods.

Sampler Type			
	A, B, C	D, E, F	G, H
Gear Used:	A: 17' boat B: 16' boat C: 12' or 14' boat	D: Canoe w/ rattail cathode E: Smith Root Tote Barge System w/ cathode plate F: Longline (150m extension cord)	G: Smith-Root 1.5 KVA w/ Longline (75m extension cord) H: Smith-Root Model LR-24 backpack
Power Source:	A, B: EG 5000 X Honda Generator with a Smith Root type VI-A (17' or 16' boat) C: Briggs & Stratton 5 HP Generator, Smith Root GPP 2.5 portable electrofisher (RCB-6B Junction Box) in 12' or 14' boat	D, E, and F: Briggs & Stratton 5 HP Generator, Smith Root GPP 2.5 portable electrofisher (RCB-6B Junction Box)	G: Honda EU2000iA generator H: 24V 7Ah battery with will run 40 minutes continuous at 100W
Current Type:	Pulsed DC	Pulsed DC	Pulsed DC
Wattage: (AC Power Source)	A,B: 5000 (17' or 16' boat) C: 2500 (12' or 14' boat)	2500	G:2000
Volts: (DC Output)	A,B: 0-1020, (suggest 340) C: 50-1000 (suggest 300)	50-1000 (suggest 300)	G: 0-560 H: 50-990 (suggest 100-300)
Amperage: (Output)	A,B: 3-6 C: 5	2-4	2-4
Anode Location:	A,B: Electrosphere on boom C: Electrosphere on boom (Large River) or Smith-Root dropper (river with fast current and/or non-wadeable pools)	Smith-Root teardrop, ring, or dropper anode	Smith-Root teardrop or ring anode
Number of Netters & Net Mesh Size:	A,B:2 people netting in the front of the boat with 1/8 inch nets C: 1 person with 1/8 inch net	2 people netting near anode with 1/8 inch nets	1-2 people netting near anode with 1/8 inch net
Distance Sampled: (meters)	15 times the width up to a maximum of 500 m (both banks)	15 times the width, maximum 500 m minimum 50 m	15 times the width, maximum 500 m minimum 50 m
Sampling Direction:	Downstream and circling around to net fish behind boat (dependent on flow)	Upstream zigzag to collect from all habitats possible	Upstream zigzag to collect from all habitats possible
Stream Size:	A,B: large/great rivers C: Non-wadeable streams	Wadeable streams to headwater tributaries	Headwater tributaries
Sampling Period:	Sept.15-Oct. 15, daytime	June-Oct. 15, daytime	June-Oct.15, daytime

Appendix B

BCG Attribute Assignments – Fish

Table B1. Fish taxa that occurred in the BCG dataset (2000-2013).

Table B2. Fish taxa that were assessed but that did not occur in the 2000-2013 BCG dataset.

Table B3. Panelists considered alternate attribute assignments for these taxa.

BCG attribute assignments are color-coded as follows –

BCG Attribute	Description
I	Historically documented, sensitive, long-lived or regionally endemic taxa
II	Highly sensitive taxa, often occur in low abundance
III	Intermediate sensitive taxa
IV	Taxa of intermediate tolerance
V	Tolerant native taxa
VI	Non-native tolerant taxa
VIi	Non-native intolerant taxa
X	Indicating ecosystem connectivity (e.g., catadromous fish)
NA	No attribute assignment (insufficient information)

Table B1. Indiana BCG attribute assignments for fish that occurred in the BCG dataset (2000-2013). This list is sorted by family, then by scientific name. CCBP = Central Corn Belt Plains, ECBP_IP = Eastern Corn Belt Plains + Interior Plateau, IRL = Interior River Lowlands, SMNIDP = Southern Michigan/Northern Indiana Drift Plains, Large River ≥ 1000 mi^2.

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
I	Acipenseridae	Scaphirhynchus platorynchus	Shovelnose Sturgeon			30		36
IV	Amiidae	Amia calva	Bowfin	15	9	25	5	6
X	Anguillidae	Anguilla rostrata	American Eel		1			
IV	Aphredoderidae	Aphredoderus sayanus	Pirate Perch	47	34	141	67	
IV	Atherinopsidae	Labidesthes sicculus	Brook Silverside		144	84		36
IV	Catostomidae	Carpiodes carpio	River Carpsucker	14	217	47		512
IV	Catostomidae	Carpiodes cyprinus	Quillback	15	321	34	6	107
III	Catostomidae	Carpiodes velifer	Highfin Carpsucker		38	8	14	21
V	Catostomidae	Catostomus commersoni	White Sucker	1381	8360	231	1179	7
III	Catostomidae	Cycleptus elongatus	Blue Sucker			11		150
IV	Catostomidae	Erimyzon oblongus	Creek Chubsucker	151	696	58	6	
IV	Catostomidae	Erimyzon sucetta	Lake Chubsucker	22	7		1	
III	Catostomidae	Hypentelium nigricans	Northern Hog Sucker	140	6484	166	118	321
IV	Catostomidae	Ictiobus bubalus	Smallmouth Buffalo	2	57	78		240
IV	Catostomidae	Ictiobus cyprinellus	Bigmouth Buffalo	9	9	138		107
IV	Catostomidae	Ictiobus niger	Black Buffalo	4	14	15	8	37
IV	Catostomidae	Minytrema melanops	Spotted Sucker	37	446	51	37	38
III	Catostomidae	Moxostoma anisurum	Silver Redhorse	10	320	16	2	130
III	Catostomidae	Moxostoma carinatum	River Redhorse	6	13		19	24
III	Catostomidae	Moxostoma duquesnei	Black Redhorse	31	4588	64	15	164
III	Catostomidae	Moxostoma erythrurum	Golden Redhorse	204	4099	86	244	293
III	Catostomidae	Moxostoma macrolepidotum	Shorthead Redhorse	171	391	15	72	526
II	Catostomidae	Moxostoma valenciennesi	Greater Redhorse		1			
IV	Centrarchidae	Ambloplites rupestris	Rock Bass	323	2387	36	435	94

Table B1. continued…

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
IV	Centrarchidae	Centrarchus macropterus	Flier			4		
V	Centrarchidae	Lepomis cyanellus	Green Sunfish	3426	8769	671	876	171
IV	Centrarchidae	Lepomis gibbosus	Pumpkinseed	258	8		27	12
IV	Centrarchidae	Lepomis gulosus	Warmouth	25	91	39	28	7
IV	Centrarchidae	Lepomis humilis	Orangespotted Sunfish	36	114	45		66
IV	Centrarchidae	Lepomis macrochirus	Bluegill	1834	6931	996	944	741
IV	Centrarchidae	Lepomis megalotis	Longear Sunfish	956	14450	1961	225	1475
IV	Centrarchidae	Lepomis microlophus	Redear Sunfish	8	128	14	44	10
III	Centrarchidae	Lepomis miniatus	Redspotted Sunfish			3		
V	Centrarchidae	Lepomis x-hybrid	Hybrid Sunfish	2	22	4		2
IV	Centrarchidae	Micropterus dolomieui	Smallmouth Bass	160	1778	19	82	221
IV	Centrarchidae	Micropterus punctulatus	Spotted Bass	35	702	229	39	549
V	Centrarchidae	Micropterus salmoides	Largemouth Bass	318	840	80	172	154
IV	Centrarchidae	Pomoxis annularis	White Crappie	11	130	18	1	30
IV	Centrarchidae	Pomoxis nigromaculatus	Black Crappie	50	73	23	10	27
IV	Clupeidae	Alosa chrysochloris	Skipjack Herring		3	2		6
VI	Clupeidae	Alosa pseudoharengus	Alewife	4			1	
IV	Clupeidae	Dorosoma cepedianum	Gizzard Shad	43	2443	236	55	1376
VI	Clupeidae	Dorosoma petenense	Threadfin Shad					15
VI	Cobitidae	Misgurnus anguillicaudatus	Oriental Weatherfish	1			1	
III	Cottidae	Cottus bairdi	Mottled Sculpin	192	3179	44	543	3
III	Cottidae	Cottus carolinae	Banded Sculpin		577			
IV	Cyprinidae	Campostoma anomalum	Central Stoneroller	4202	41604	981	728	23
IV	Cyprinidae	Campostoma oligolepis	Largescale Stoneroller	72	4235		2	74
VI	Cyprinidae	Carassius auratus	Goldfish	31	118		1	
II	Cyprinidae	Clinostomus elongatus	Redside Dace		46			

Table B1. continued…

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
VI	Cyprinidae	Ctenopharyngodon idella	Grass Carp					10
IV	Cyprinidae	Cyprinella spiloptera	Spotfin Shiner	848	4228	1084	230	3015
IV	Cyprinidae	Cyprinella whipplei	Steelcolor Shiner	46	638	290	34	145
VI	Cyprinidae	Cyprinus carpio	Common Carp	556	933	313	121	578
IV	Cyprinidae	Ericymba buccata	Silverjaw Minnow	549	8266	1267	18	8
II	Cyprinidae	Erimystax dissimilis	Streamline Chub		50		7	79
II	Cyprinidae	Erimystax x-punctatus	Gravel Chub		4			22
IV	Cyprinidae	Hybognathus hayi	Cypress Minnow			2		
IV	Cyprinidae	Hybognathus nuchalis	Mississippi Silvery Minnow	1	257	198		102
III	Cyprinidae	Hybopsis amblops	Bigeye Chub	16	3024	83	5	134
VI	Cyprinidae	Hypophthalmichthys molitrix	Silver Carp			13		33
VI	Cyprinidae	Hypophthalmichthys nobilis	Bighead Carp					5
IV	Cyprinidae	Luxilus chrysocephalus	Striped Shiner	2037	9750	125	387	7
IV	Cyprinidae	Luxilus cornutus	Common Shiner	13	3		96	
III	Cyprinidae	Lythrurus fasciolaris	Scarletfin Shiner		354			
IV	Cyprinidae	Lythrurus fumeus	Ribbon Shiner		61	146		1
IV	Cyprinidae	Lythrurus umbratilis	Redfin Shiner	67	885	334	2	1
III	Cyprinidae	Macrhybopsis hyostoma	Shoal Chub			1		
IV	Cyprinidae	Macrhybopsis storeriana	Silver Chub			5		19
III	Cyprinidae	Nocomis biguttatus	Hornyhead Chub	1145	258		403	2
III	Cyprinidae	Nocomis micropogon	River Chub		426		12	1
V	Cyprinidae	Notemigonus crysoleucas	Golden Shiner	361	137	29	24	7
III	Cyprinidae	Notropis ariommus	Popeye Shiner		3			
IV	Cyprinidae	Notropis atherinoides	Emerald Shiner	3	198	85		562
IV	Cyprinidae	Notropis blennius	River Shiner		18	13		37
III	Cyprinidae	Notropis boops	Bigeye Shiner		343			5

Table B1. continued…

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
IV	Cyprinidae	Notropis buchanani	Ghost Shiner		62			12
III	Cyprinidae	Notropis chalybaeus	Ironcolor Shiner	36				
II	Cyprinidae	Notropis heterodon	Blackchin Shiner	4	5		1	
II	Cyprinidae	Notropis heterolepis	Blacknose Shiner	2			1	
III	Cyprinidae	Notropis photogenis	Silver Shiner		379			28
III	Cyprinidae	Notropis rubellus	Rosyface Shiner	52	955		66	25
IV	Cyprinidae	Notropis stramineus	Sand Shiner	989	3274	204	60	323
II	Cyprinidae	Notropis texanus	Weed Shiner	12				
III	Cyprinidae	Notropis volucellus	Mimic Shiner	7	433		5	1
IV	Cyprinidae	Notropis wickliffi	Channel Shiner		12	1		3
III	Cyprinidae	Opsopoeodus emiliae	Pugnose Minnow		32	1		2
IV	Cyprinidae	Phenacobius mirabilis	Suckermouth Minnow	13	469	29		14
III	Cyprinidae	Phoxinus erythrogaster	Southern Redbelly Dace	79	1138	70		
V	Cyprinidae	Pimephales notatus	Bluntnose Minnow	3332	29546	2881	415	288
V	Cyprinidae	Pimephales promelas	Fathead Minnow	324	1702	9	90	
IV	Cyprinidae	Pimephales vigilax	Bullhead Minnow		334	326		776
III	Cyprinidae	Rhinichthys cataractae	Longnose Dace				63	
IV	Cyprinidae	Rhinichthys obtusus	Western Blacknose Dace	833	6419	308	904	5
V	Cyprinidae	Semotilus atromaculatus	Creek Chub	5220	27119	1533	1624	7
IV	Esocidae	Esox americanus	Grass Pickerel	237	336	57	100	12
IV	Esocidae	Esox lucius	Northern Pike	18			2	6
IV	Fundulidae	Fundulus catenatus	Northern Studfish		11			
IV	Fundulidae	Fundulus dispar	Northern Starhead Topminnow	28				
V	Fundulidae	Fundulus notatus	Blackstripe Topminnow	390	854	474	17	9
IV	Gasterosteidae	Culaea inconstans	Brook Stickleback	19			2	
VI	Gobiidae	Neogobius melanostomus	Round Goby	2			102	

Table B1. continued…

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
II	Hiodontidae	Hiodon alosoides	Goldeye					10
III	Hiodontidae	Hiodon tergisus	Mooneye					8
VI	Ictaluridae	Ameiurus catus	White Catfish		2			1
V	Ictaluridae	Ameiurus melas	Black Bullhead	142	313	3	36	
V	Ictaluridae	Ameiurus natalis	Yellow Bullhead	239	945	285	79	6
V	Ictaluridae	Ameiurus nebulosus	Brown Bullhead	18	20	15	2	
IV	Ictaluridae	Ictalurus furcatus	Blue Catfish	1				4
IV	Ictaluridae	Ictalurus punctatus	Channel Catfish	80	284	126	9	477
II	Ictaluridae	Noturus eleutherus	Mountain Madtom		1			4
III	Ictaluridae	Noturus flavus	Stonecat	4	101	5	5	14
IV	Ictaluridae	Noturus gyrinus	Tadpole Madtom	67	50	14	7	1
III	Ictaluridae	Noturus miurus	Brindled Madtom	7	192	11		3
II	Ictaluridae	Noturus nocturnus	Freckled Madtom					2
IV	Ictaluridae	Pylodictis olivaris	Flathead Catfish	6	49	34	1	164
IV	Lepisosteidae	Lepisosteus oculatus	Spotted Gar	1	5	5	1	4
IV	Lepisosteidae	Lepisosteus osseus	Longnose Gar	1	35	6		40
IV	Lepisosteidae	Lepisosteus platostomus	Shortnose Gar		1	29		158
VI	Moronidae	Morone americana	White Perch	7				
IV	Moronidae	Morone chrysops	White Bass	1	78	3	2	17
NA	Moronidae	Morone chrysopsxsaxatilis	Wiper					1
IV	Moronidae	Morone mississippiensis	Yellow Bass		7	8		5
VI	Moronidae	Morone saxatilis	Striped Bass		1			
II	Percidae	Ammocrypta pellucida	Eastern Sand Darter		17	1		16
IV	Percidae	Etheostoma asprigene	Mud Darter		11	10		6
IV	Percidae	Etheostoma blennioides	Greenside Darter	73	4852	59	32	23
IV	Percidae	Etheostoma caeruleum	Rainbow Darter	173	6395	35	189	49

Table B1. continued…

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
II	Percidae	Etheostoma camurum	Bluebreast Darter		15			8
IV	Percidae	Etheostoma chlorosomum	Bluntnose Darter			2		
IV	Percidae	Etheostoma exile	Iowa Darter		5		1	
IV	Percidae	Etheostoma flabellare	Fantail Darter	88	2716	30	3	8
IV	Percidae	Etheostoma gracile	Slough Darter		12	99		4
III	Percidae	Etheostoma histrio	Harlequin Darter		6	1		1
II	Percidae	Etheostoma maculatum	Spotted Darter		116			
IV	Percidae	Etheostoma microperca	Least Darter	309	144	2	1	
IV	Percidae	Etheostoma nigrum	Johnny Darter	1597	7927	281	1063	19
IV	Percidae	Etheostoma spectabile	Orangethroat Darter	110	5883	231	36	3
NA	Percidae	Etheostoma spectabilexcaeruleum	Orangethroat Rainbow Hybrid		52			
II	Percidae	Etheostoma squamiceps	Spottail Darter			14		
II	Percidae	Etheostoma tippecanoe	Tippecanoe Darter					13
II	Percidae	Etheostoma variatum	Variegate Darter		10			20
III	Percidae	Etheostoma zonale	Banded Darter	104	209	1	45	120
IV	Percidae	Perca flavescens	Yellow Perch	2	1	4	18	3
IV	Percidae	Percina caprodes	Logperch	26	732	20	76	96
IV	Percidae	Percina maculata	Blackside Darter	89	124	35	120	15
III	Percidae	Percina phoxocephala	Slenderhead Darter	35	38	2		54
IV	Percidae	Percina sciera	Dusky Darter	17	371	153	13	136
III	Percidae	Percina shumardi	River Darter		4			
IV	Percidae	Sander canadense	Sauger	2	20	4	3	50
IV	Percidae	Sander vitreus	Walleye	6	8		3	16
NA	Petromyzontidae	Ammocoetes	Ammocoetes				8	
IV	Petromyzontidae	Ichthyomyzon castaneus	Chestnut Lamprey		27	11	2	22
II	Petromyzontidae	Ichthyomyzon fossor	Northern Brook Lamprey	1			4	

Table B1. continued…

BCG Attribute	Family	Scientific Name	Common Name	Number of individuals in BCG dataset				
				CCBP	ECBP_IP	IRL	SMNIDP	Large River
IV	Petromyzontidae	Ichthyomyzon unicuspis	Silver Lamprey					4
II	Petromyzontidae	Lampetra aepyptera	Least Brook Lamprey		2			
II	Petromyzontidae	Lampetra appendix	American Brook Lamprey		10	2	34	6
V	Poeciliidae	Gambusia affinis	Western Mosquitofish	2	282	1050		14
VIi	Salmonidae	Oncorhynchus kisutch	Coho Salmon				27	
VIi	Salmonidae	Oncorhynchus mykiss	Rainbow Trout	16	7		330	
VIi	Salmonidae	Oncorhynchus tshawytscha	Chinook Salmon				6	
VIi	Salmonidae	Salmo trutta	Brown Trout	3	41		162	
IV	Sciaenidae	Aplodinotus grunniens	Freshwater Drum	1	110	142		666
V	Umbridae	Umbra limi	Central Mudminnow	721	357	2	887	

Table B2. Indiana BCG attribute assignments for fish that were assessed but that did not occur in the 2000-2013 BCG dataset. This list is sorted by family, then by scientific name.

BCG Attribute	Common Name
II	Alligator Gar
IV	Banded Killifish
IV	Banded Pygmy Sunfish
IV	Bigmouth Shiner
V	Blacknose Dace Atratulus
IV	Blackspotted Topminnow
VIi	Brook Trout
III	Channel Darter
II	Crystal Darter
IV	Eastern Silvery Minnow Regius
I	Gilt Darter
II	Lake Sturgeon
II	Longnose Sucker
IV	Muskellunge
IV	Ninespine Stickleback
II	Northern Madtom
II	Ohio Lamprey
II	Paddlefish
II	Pallid Shiner
III	Pugnose Shiner
IV	Red Shiner
III	Rosefin Shiner
IV	Silverband Shiner
II	Slender Madtom
III	Smallmouth Redhorse
III	Speckled Chub
IV	Spottail Shiner
IV	Spotted Sunfish
IV	Stripetail Darter
IV	Trout-Perch
II	Western Sand Darter

Table B3. Panelists considered alternate BCG attribute assignments for these taxa.

BCG Attribute - final	BCG Attribute – previous	Common Name
IV	V	Western Blacknose Dace
III	IV	Redspotted Sunfish
III	IV	Hornyhead Chub
II	IV	Weed Shiner
III	IV	Mimic Shiner
III	IV	Pugnose Minnow
III	IV	Longnose Dace

Appendix C

Fish Capture Probability Modeled vs.
Stress Gradient

Statistical approaches to determine indicator values

As described in Yuan's (2006) review[1] of approaches for developing biological indicator values related to various environmental stressors, several different statistical approaches can be applied, including central tendencies, environmental limits and optima. Tolerance values expressed in terms of central tendencies attempt to describe the average environmental conditions under which a species is likely to occur; indicator values expressed in terms of environmental limits attempt to capture the maximum or the minimum level of an environmental variable under which a species can persist; and indicator values expressed in terms of optima define the environmental conditions that are most preferred by a given species. These types of indicator values are expressed in terms of locations on a continuous numerical scale that represents the environmental gradient of interest.

Both abundance-based and presence/absence-based models can be built using statistical approaches such as weighted averaging (WA) (used to estimate optima and tolerance values, based on abundance data); cumulative distribution function median and extreme limits (based on presence/absence data); and logistic regression (linear, nonlinear, generalized additive model (GAM)) median and extreme limits (based on presence/absence data). Results can be used to generate indicator values of optima (central tendency, WA or 50th percentile) or tolerance (limits, 5th or 95th percentile).

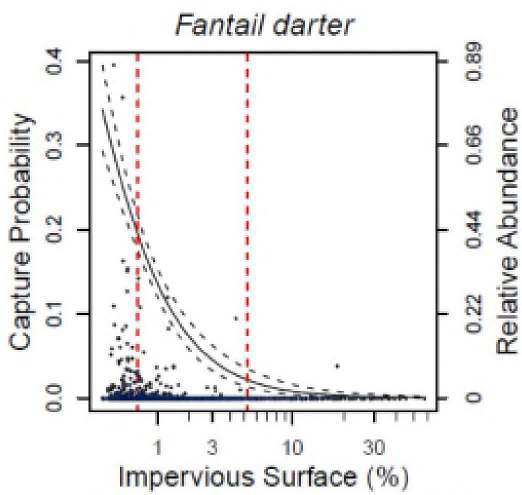
Taxon-response plots like the example shown below were generated for fish taxa that occurred in at least 10 samples in the BCG dataset. The relationships were modeled using generalized additive models (GAM). These plots were used to help inform BCG attribute assignments at the spring 2015 workshop. Plots were generated for 2 variables that represent gradients of anthropogenic disturbance in Indiana:

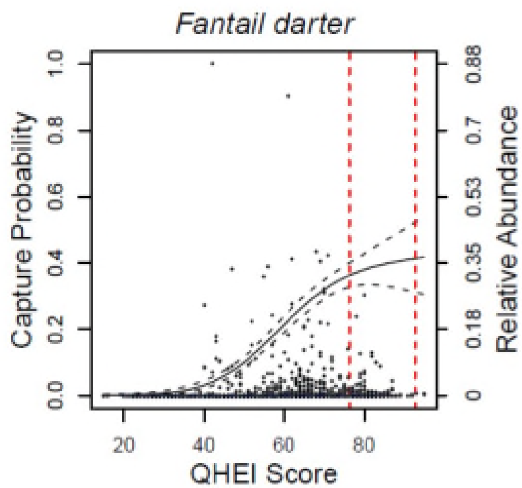
- % Imperviousness surface
- Qualitative Habitat Evaluation Index (QHEI)

[1] Yuan, Lester. 2006. Estimation and Application of Macroinvertebrate Tolerance Values. Report No. EPA/600/P-04/116F. National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

Modeled relationship between probability of occurrence of Fantail Darter, % imperviousness surface and QHEI score

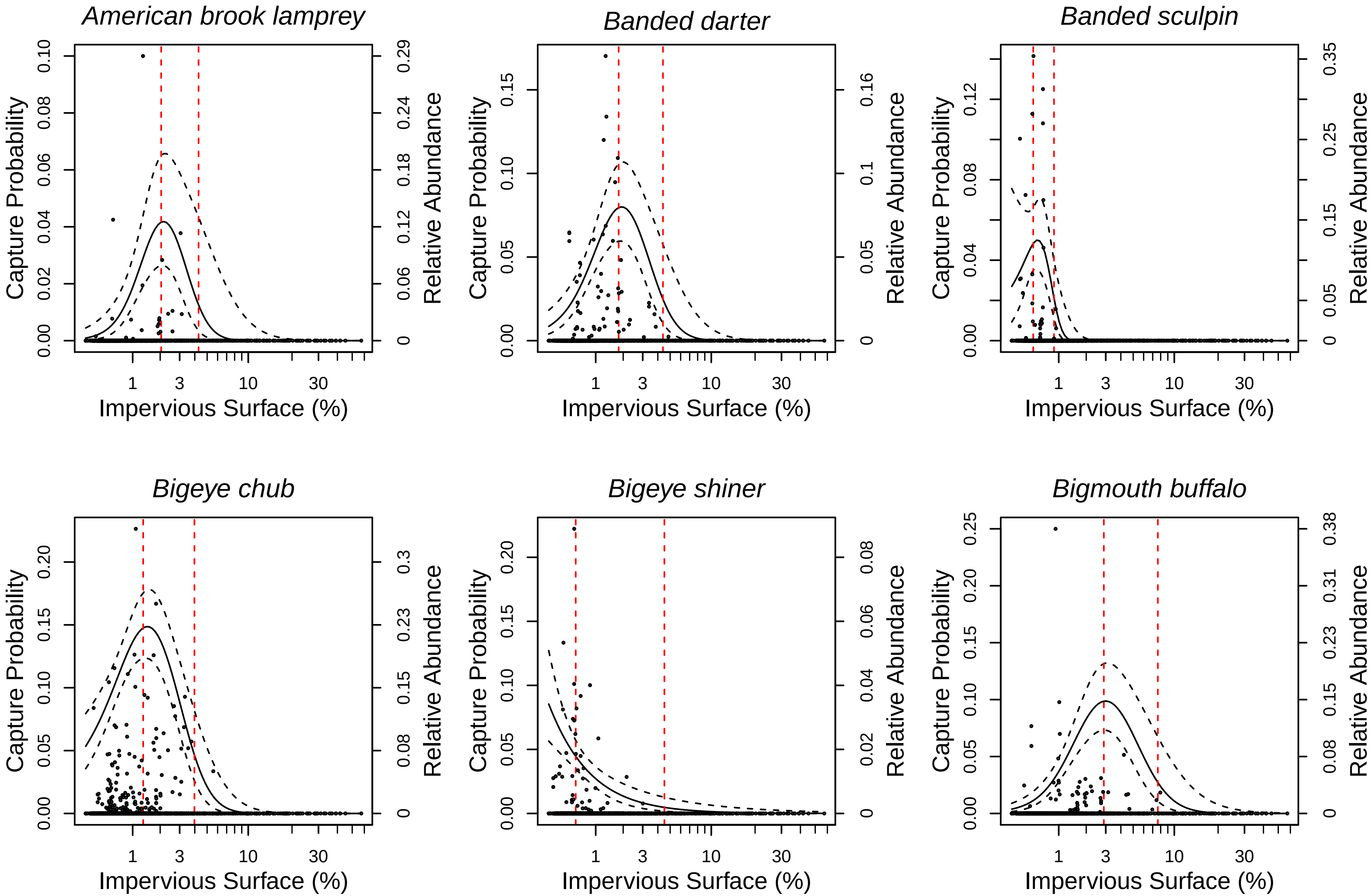
- **Points**: actual data of relative abundance
- **Curved lines**:
  - *Solid* – modeled capture probability based on the generalized additive model (GAM) fit
  - *Dotted* - estimated 90% confidence limits for the GAM model fit
- **Vertical lines**:
  - *Central tendency* - median cumulative probability
  - *Limit* - 95% cumulative probability based on the GAM model



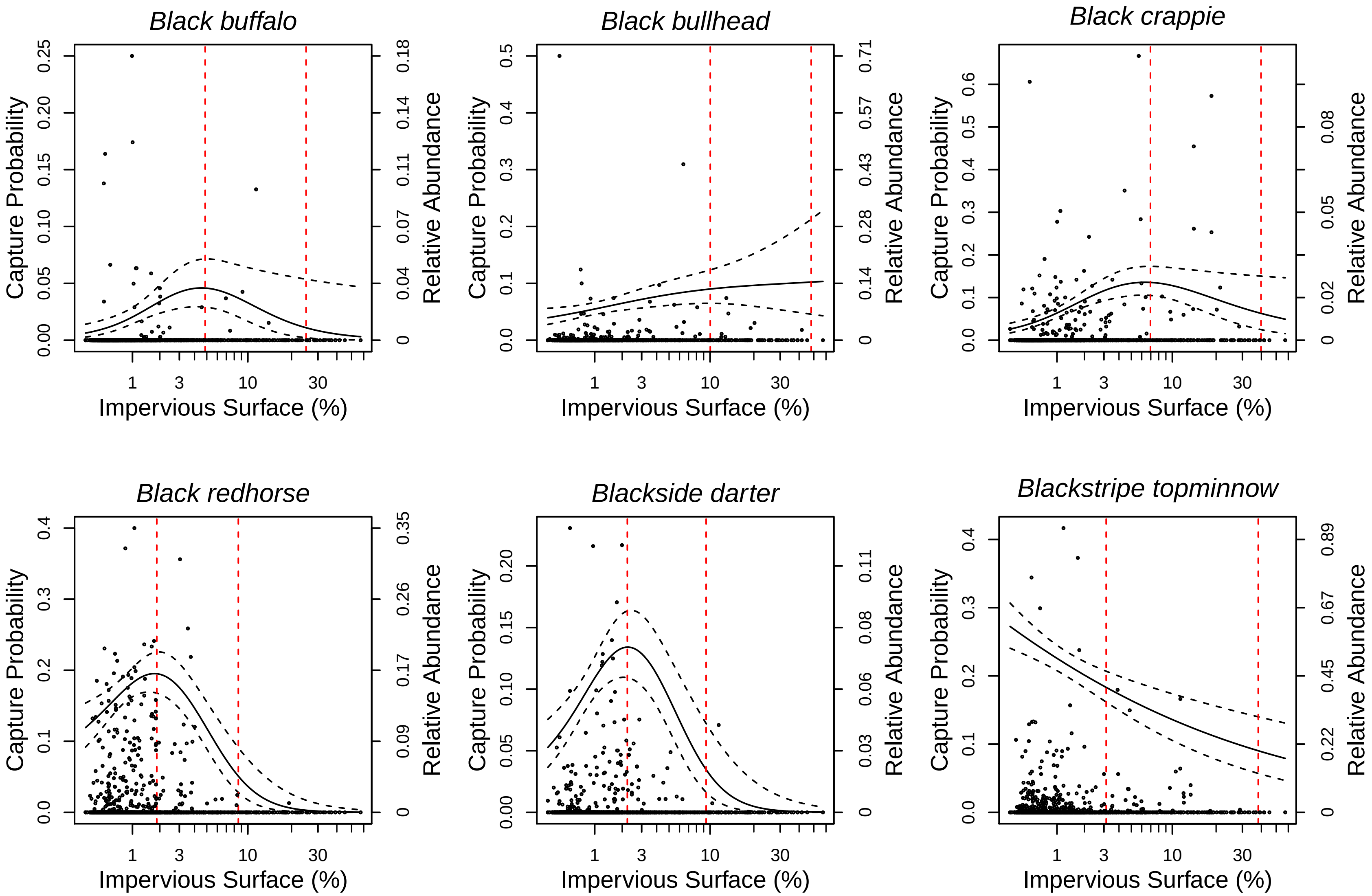


RESPONSES OF FISH TAXA TO PERCENT IMPERVIOUS SURFACE

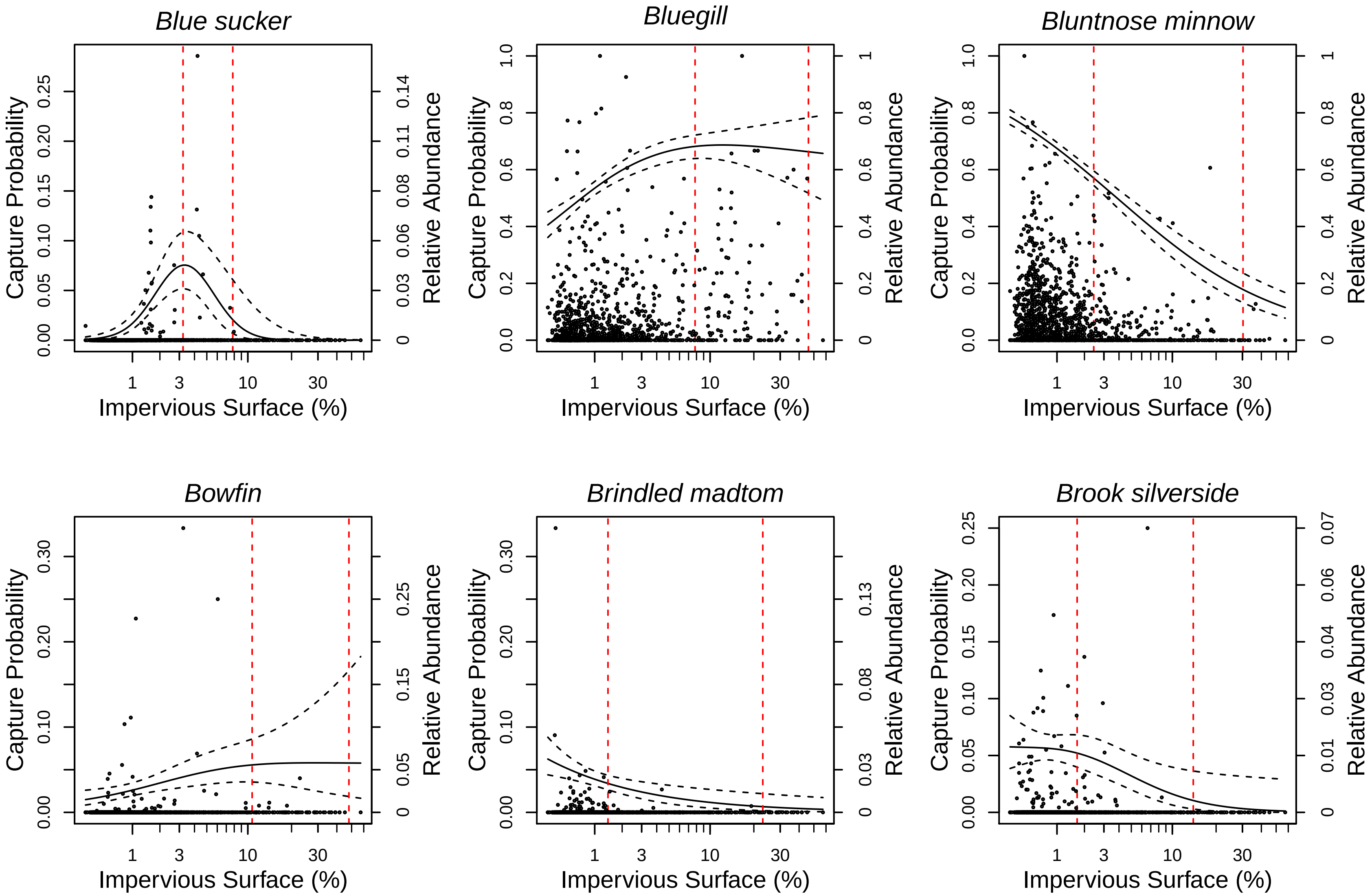
Capture Probability of Fish Taxon Along Impervious Gradient



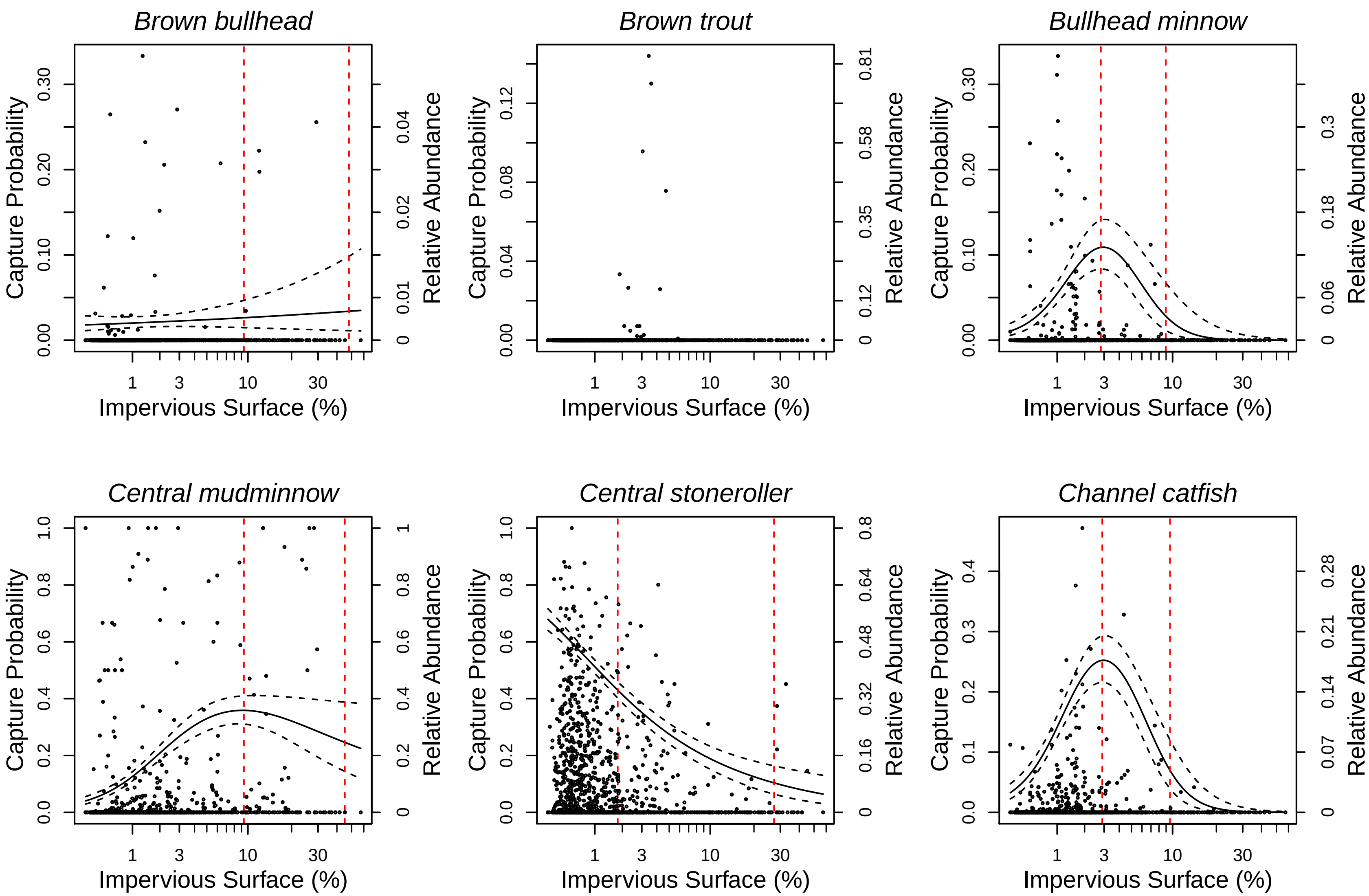
Capture Probability of Fish Taxon Along Impervious Gradient



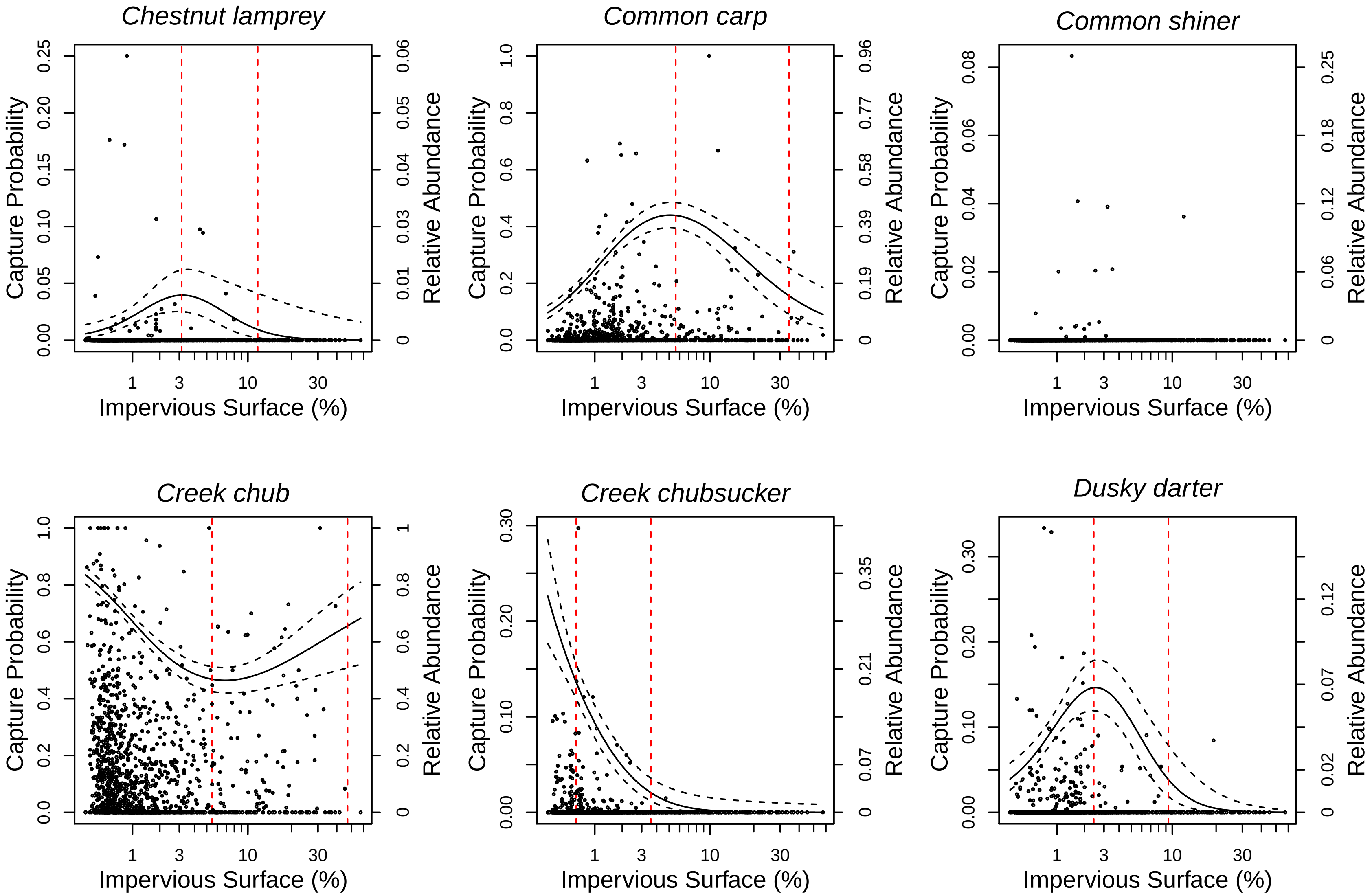
Capture Probability of Fish Taxon Along Impervious Gradient



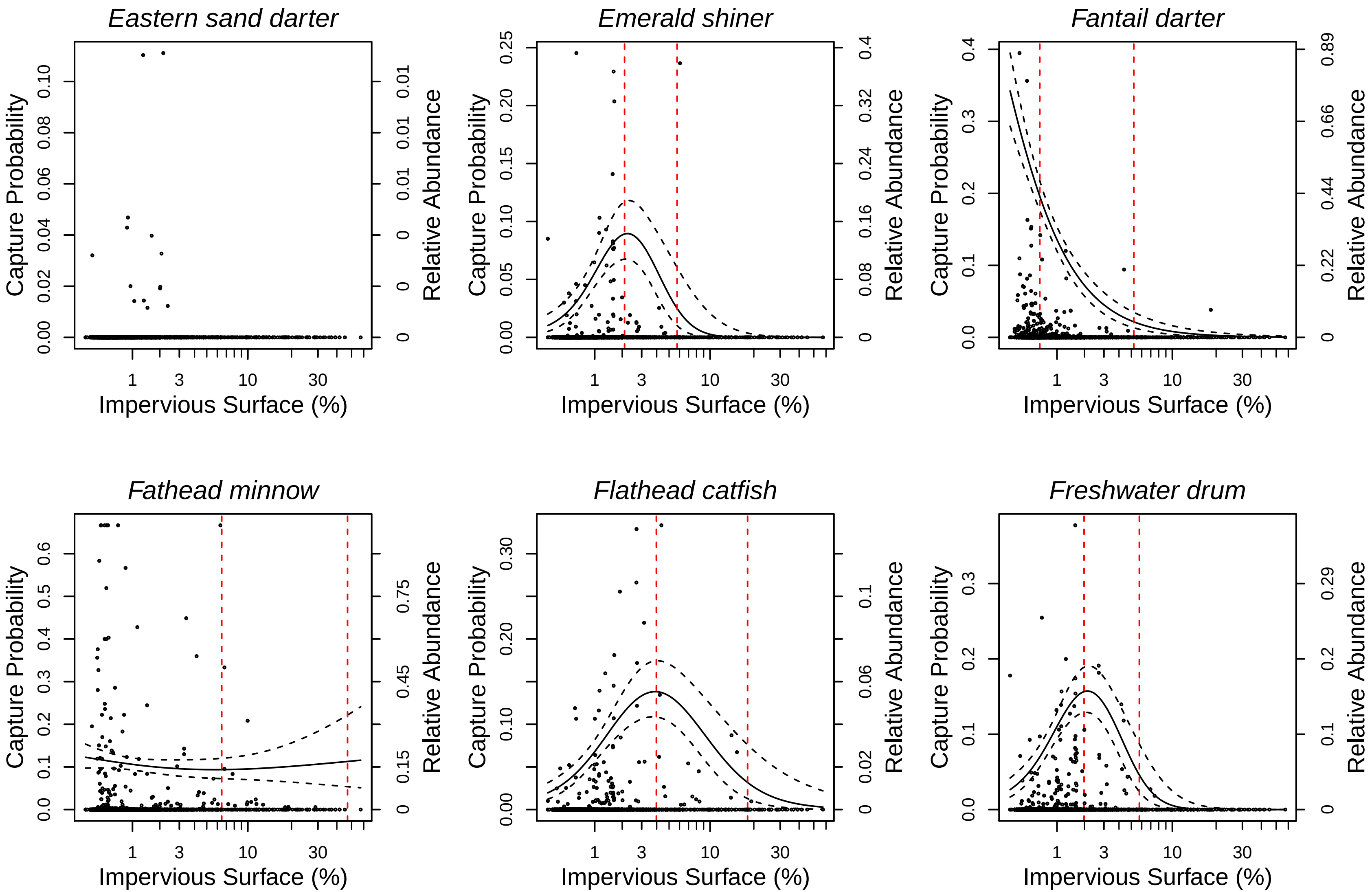
Capture Probability of Fish Taxon Along Impervious Gradient



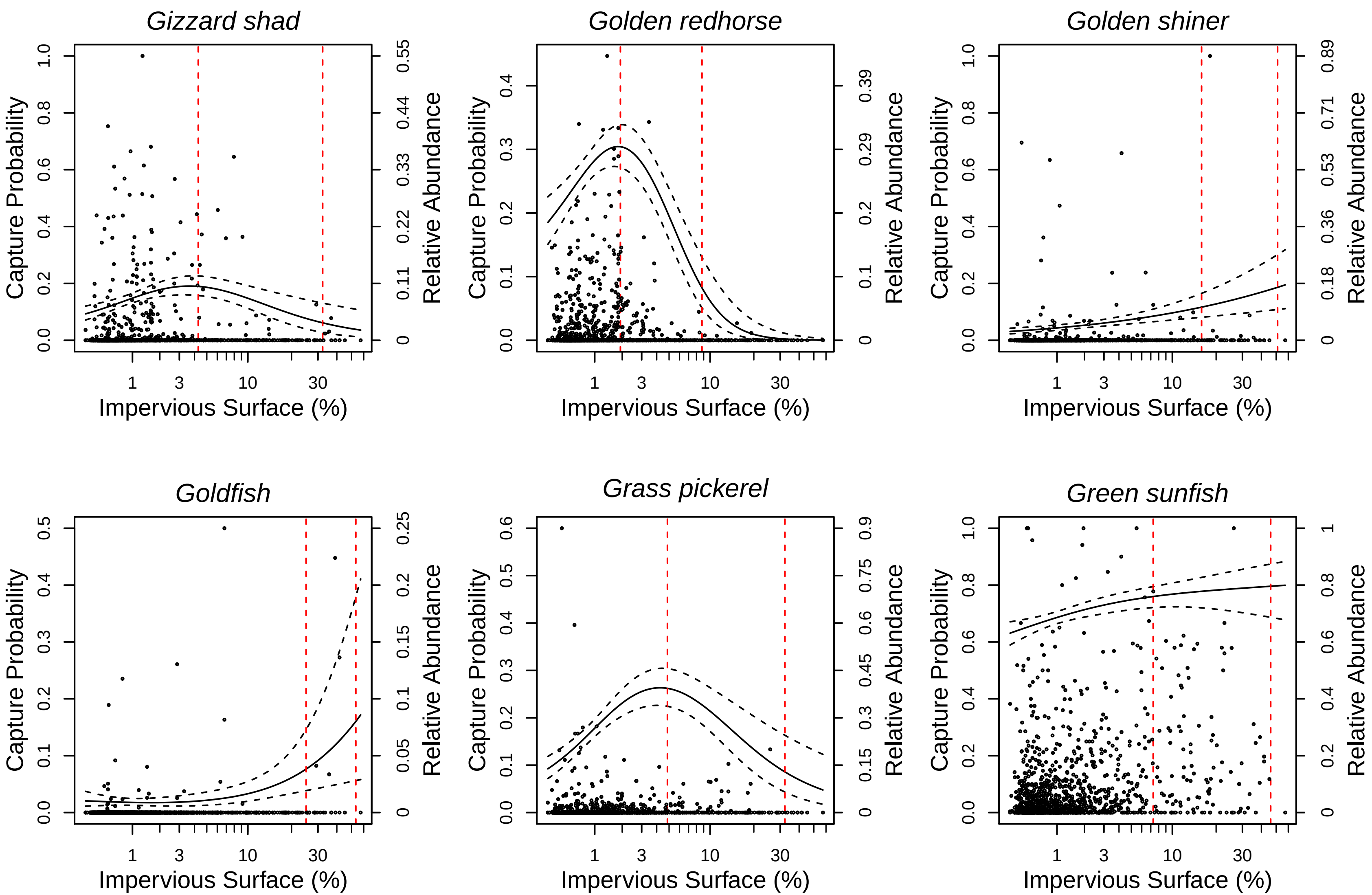
Capture Probability of Fish Taxon Along Impervious Gradient



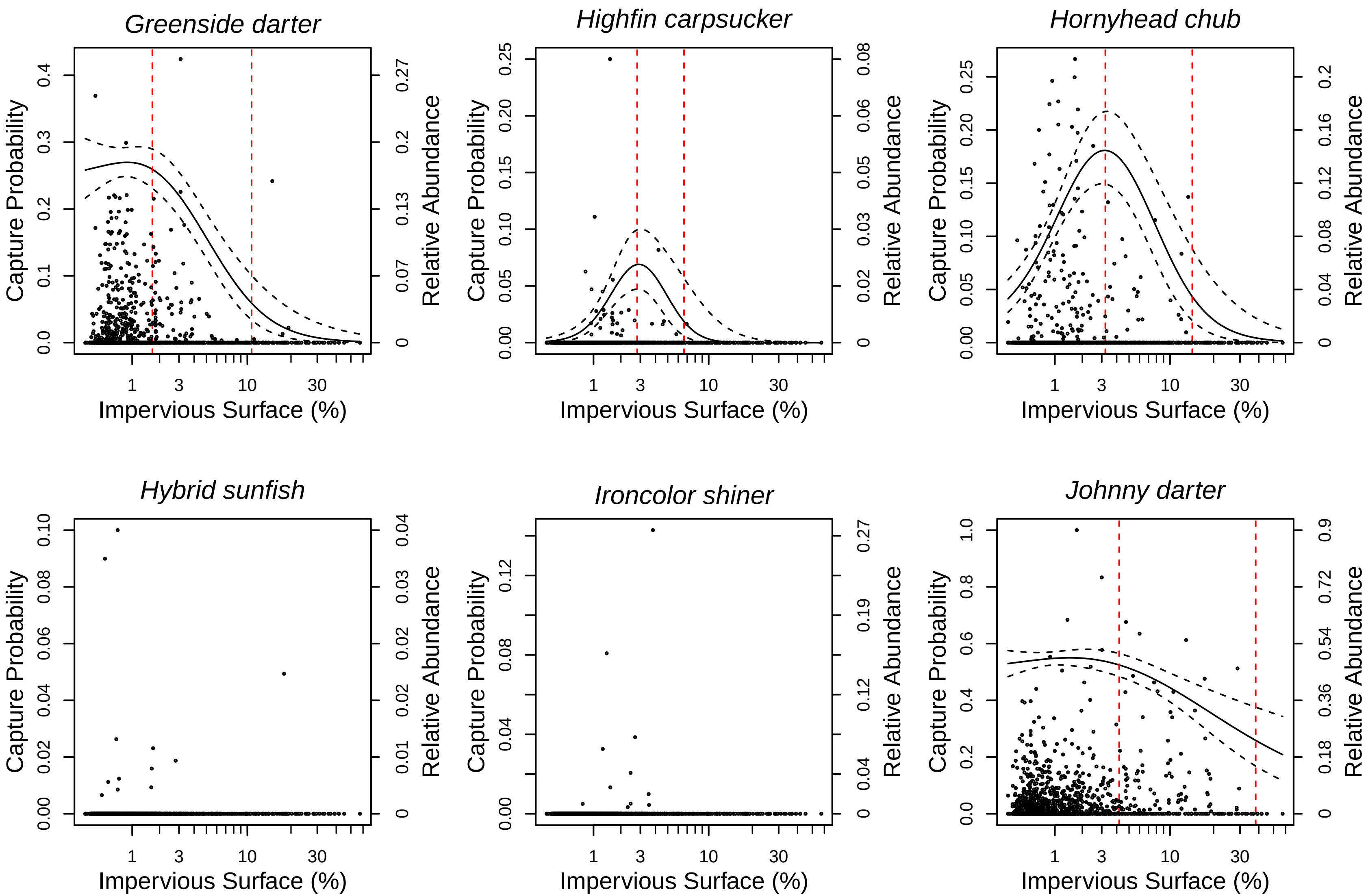
Capture Probability of Fish Taxon Along Impervious Gradient



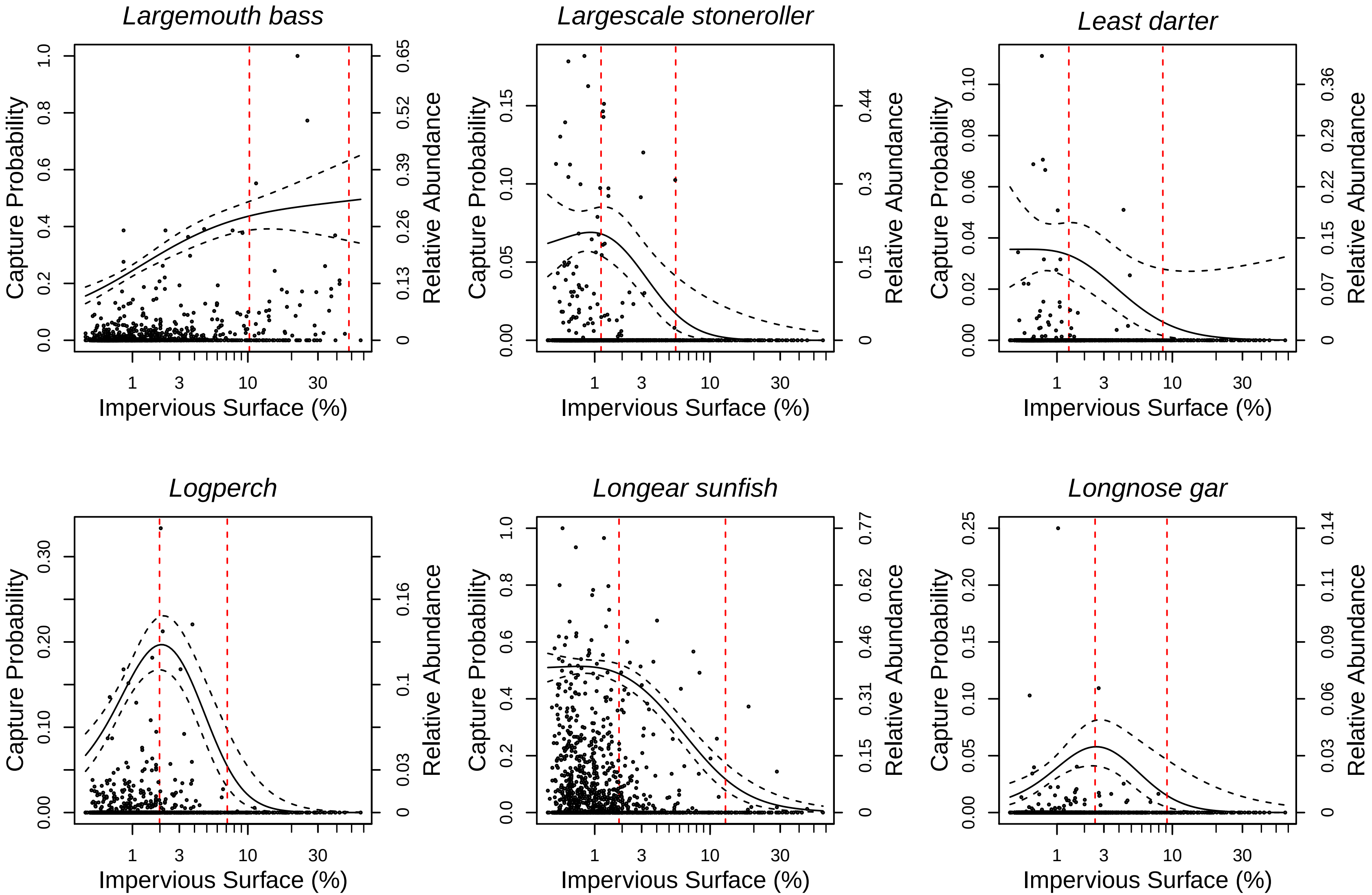
Capture Probability of Fish Taxon Along Impervious Gradient



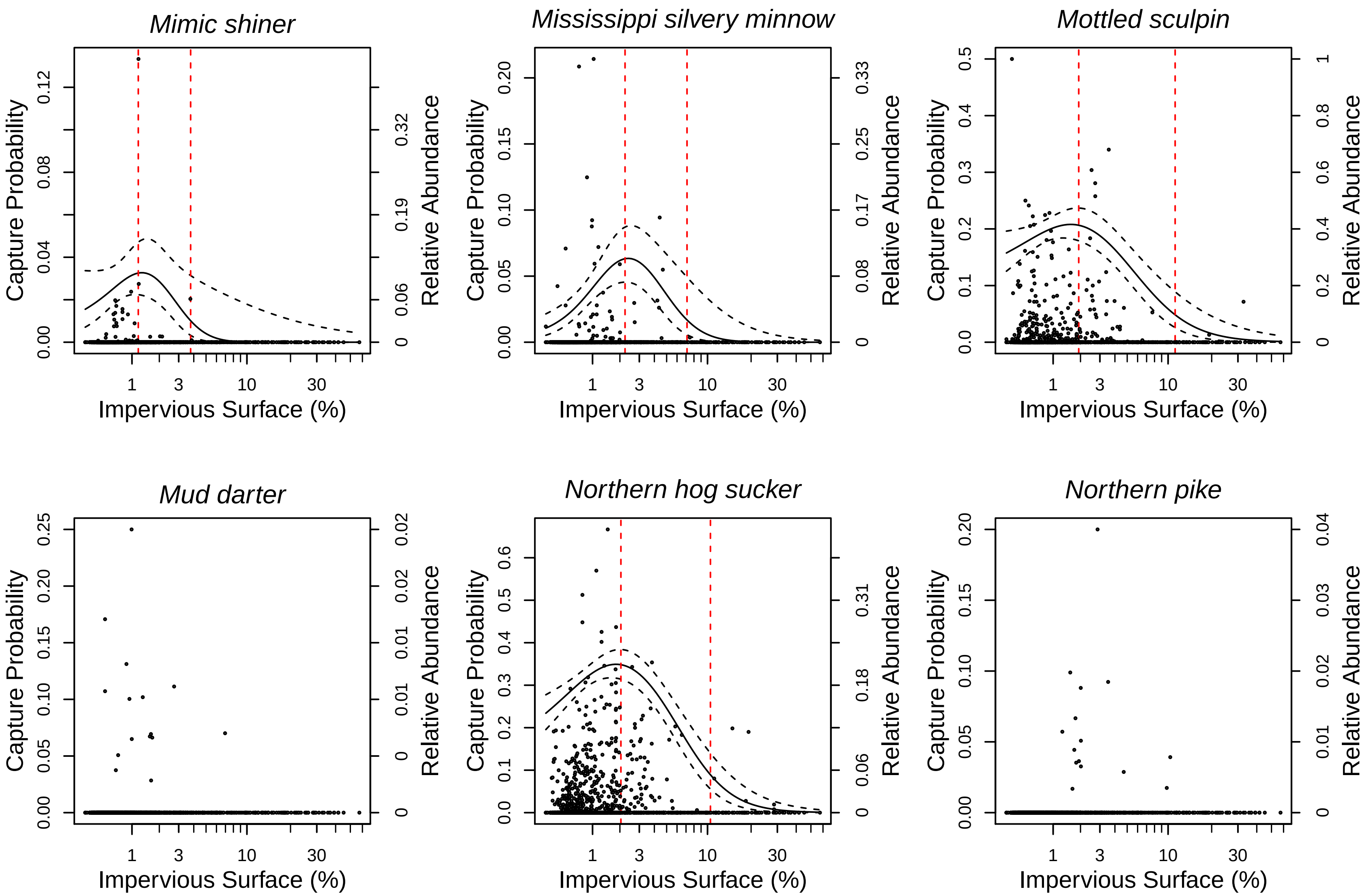
Capture Probability of Fish Taxon Along Impervious Gradient



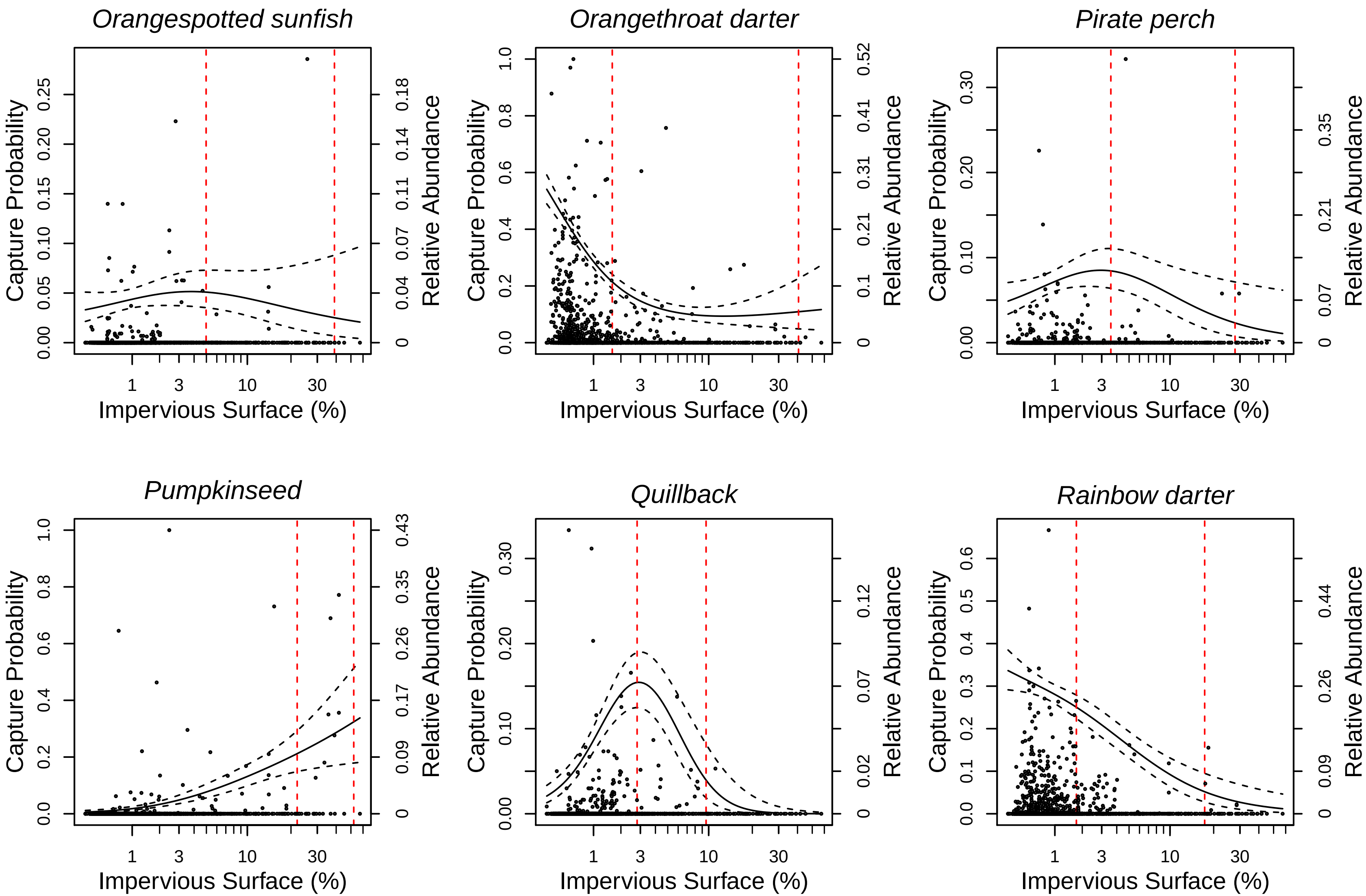
Capture Probability of Fish Taxon Along Impervious Gradient



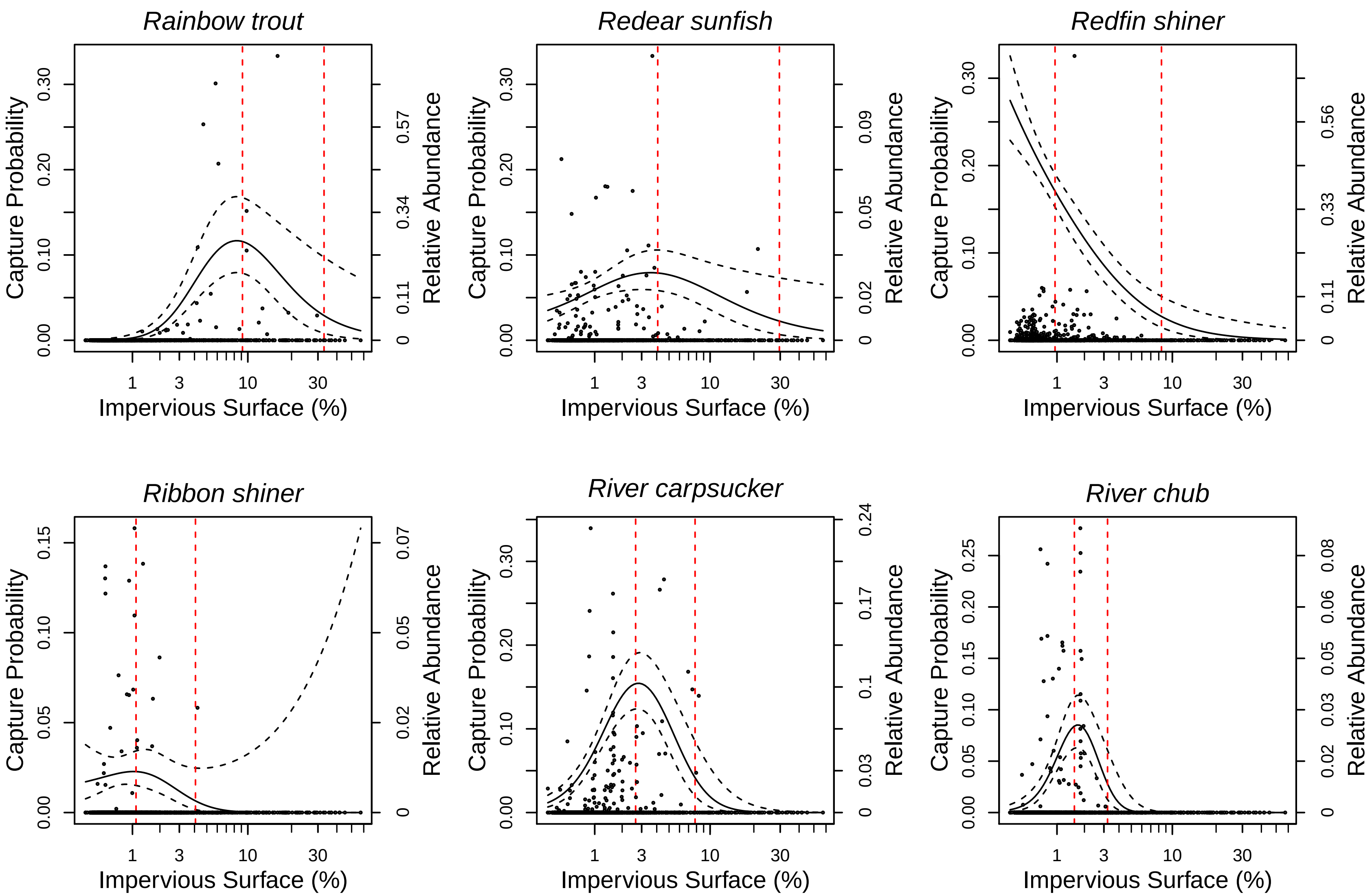
Capture Probability of Fish Taxon Along Impervious Gradient

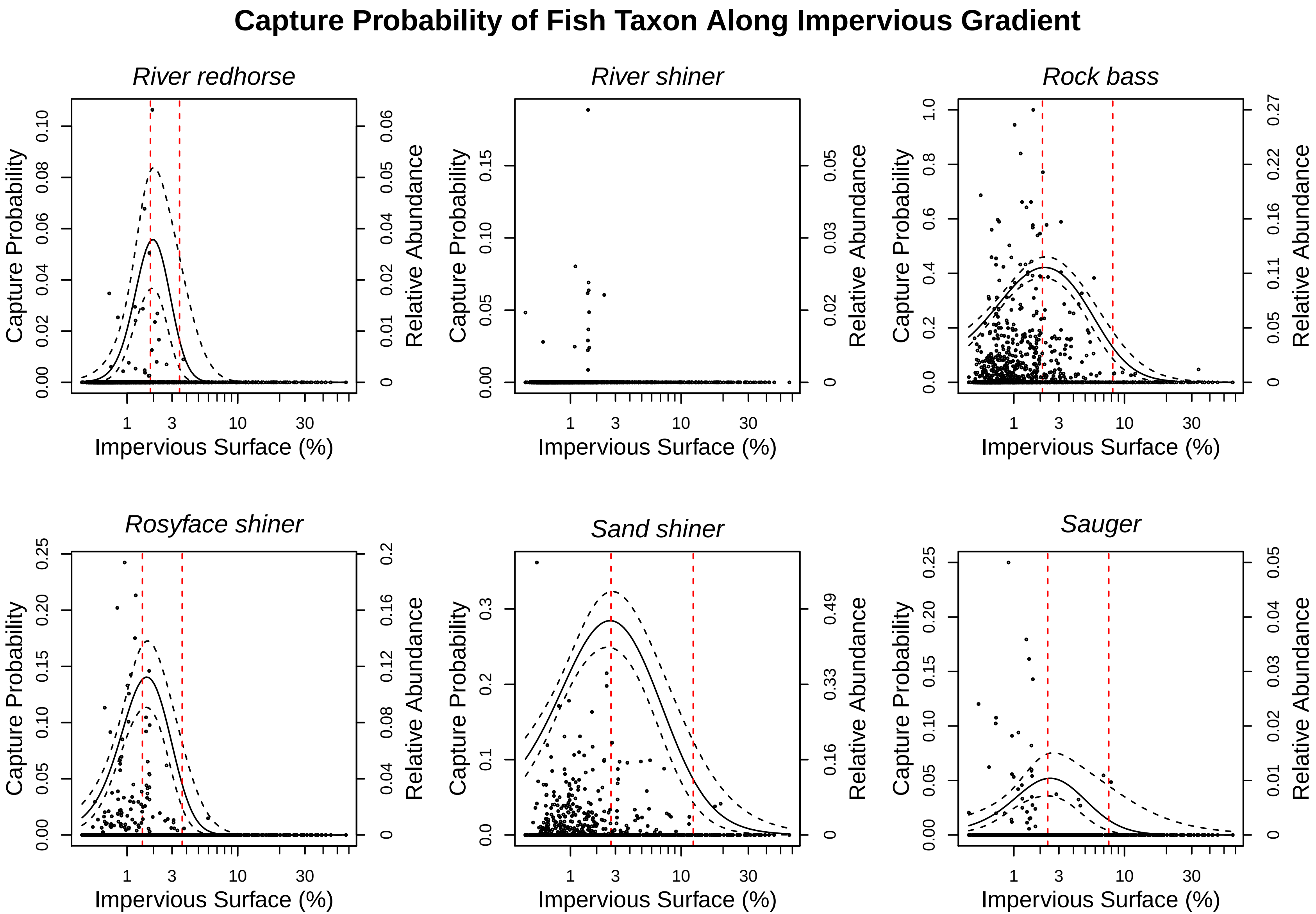


Capture Probability of Fish Taxon Along Impervious Gradient

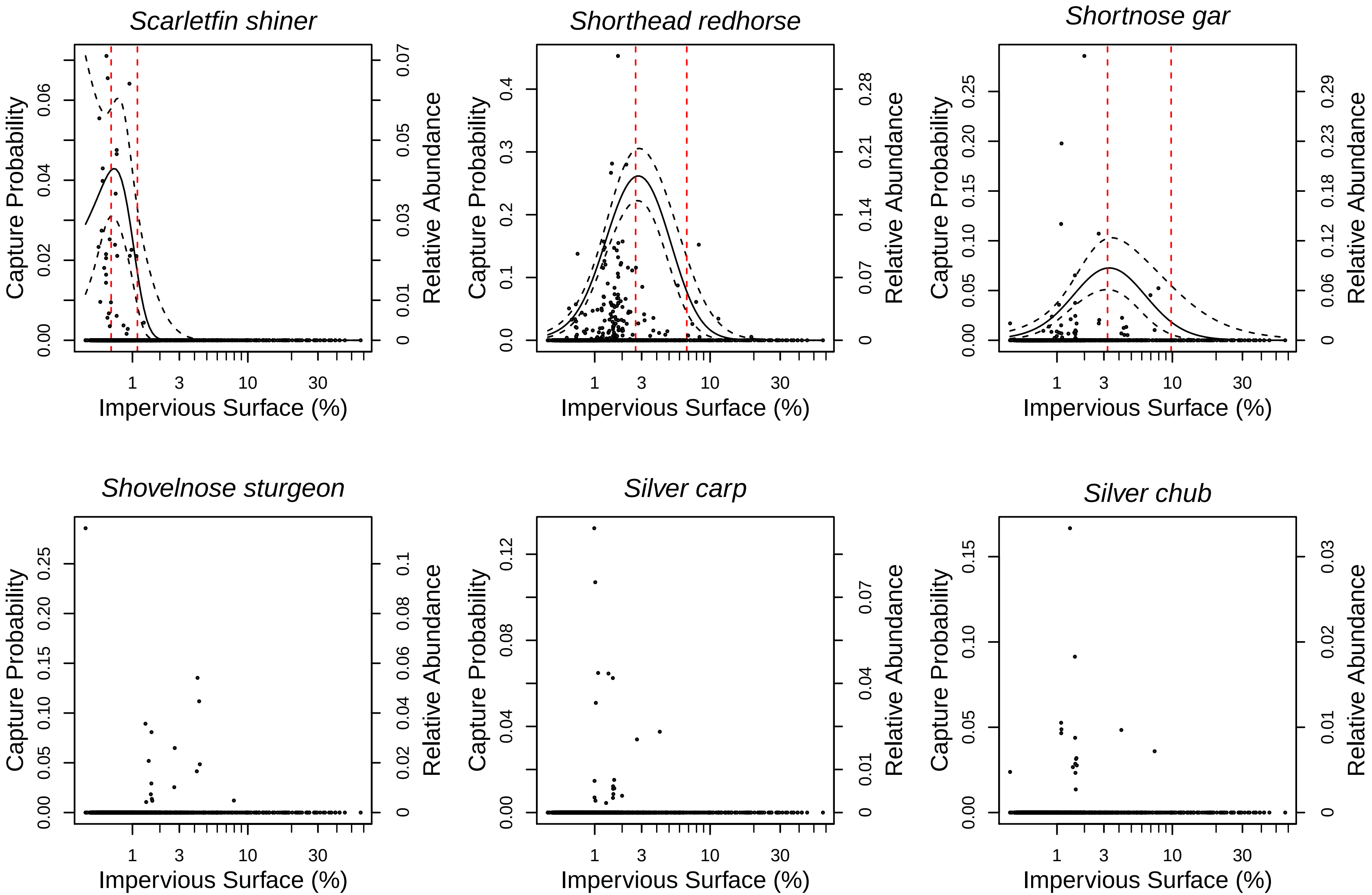


Capture Probability of Fish Taxon Along Impervious Gradient

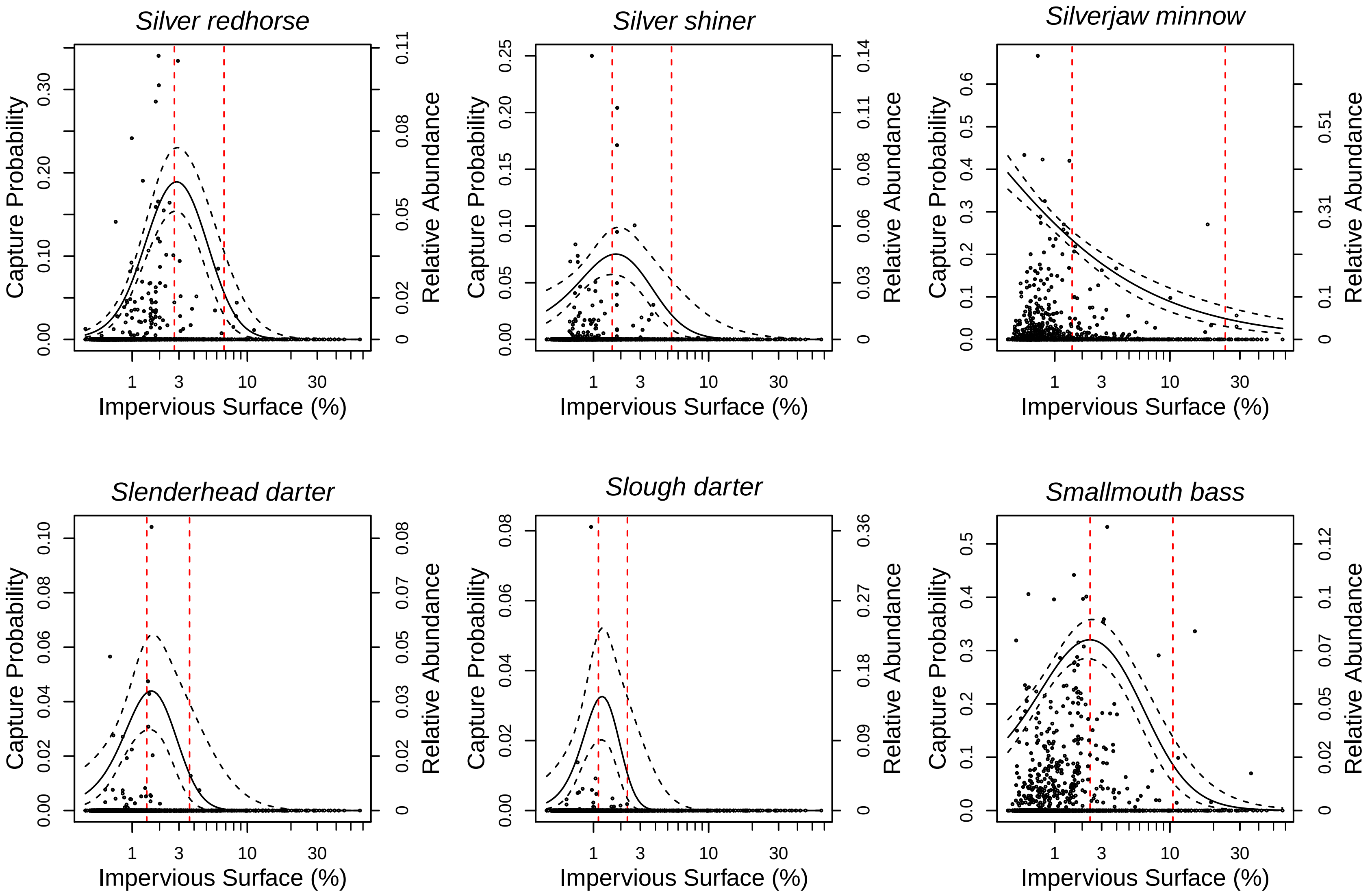



Capture Probability of Fish Taxon Along Impervious Gradient
River redhorse
River shiner
Rock bass
Rosyface shiner
Sand shiner
Sauger
Capture Probability
Relative Abundance
Impervious Surface (%)
1
3
10
30

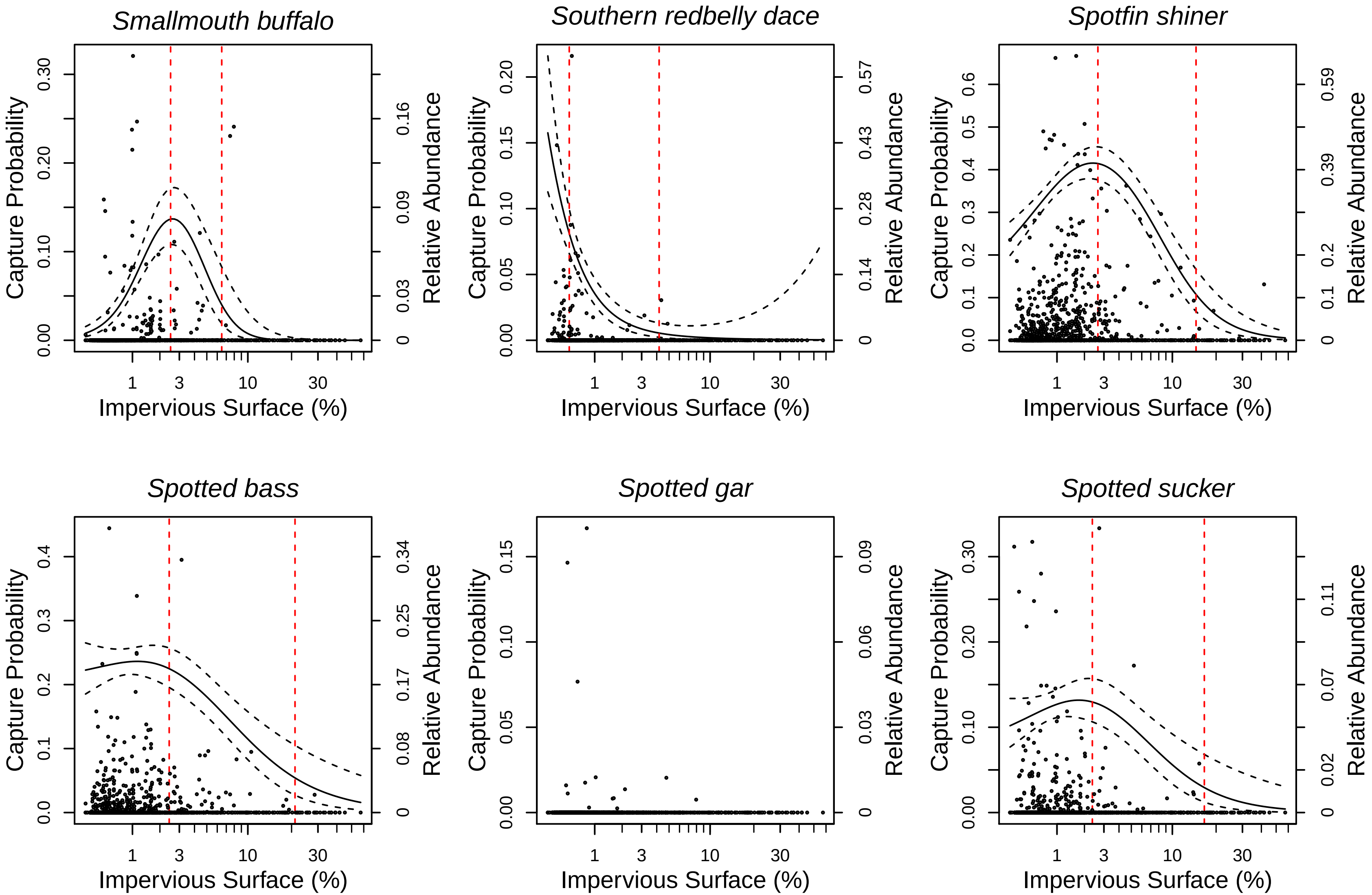
Capture Probability of Fish Taxon Along Impervious Gradient



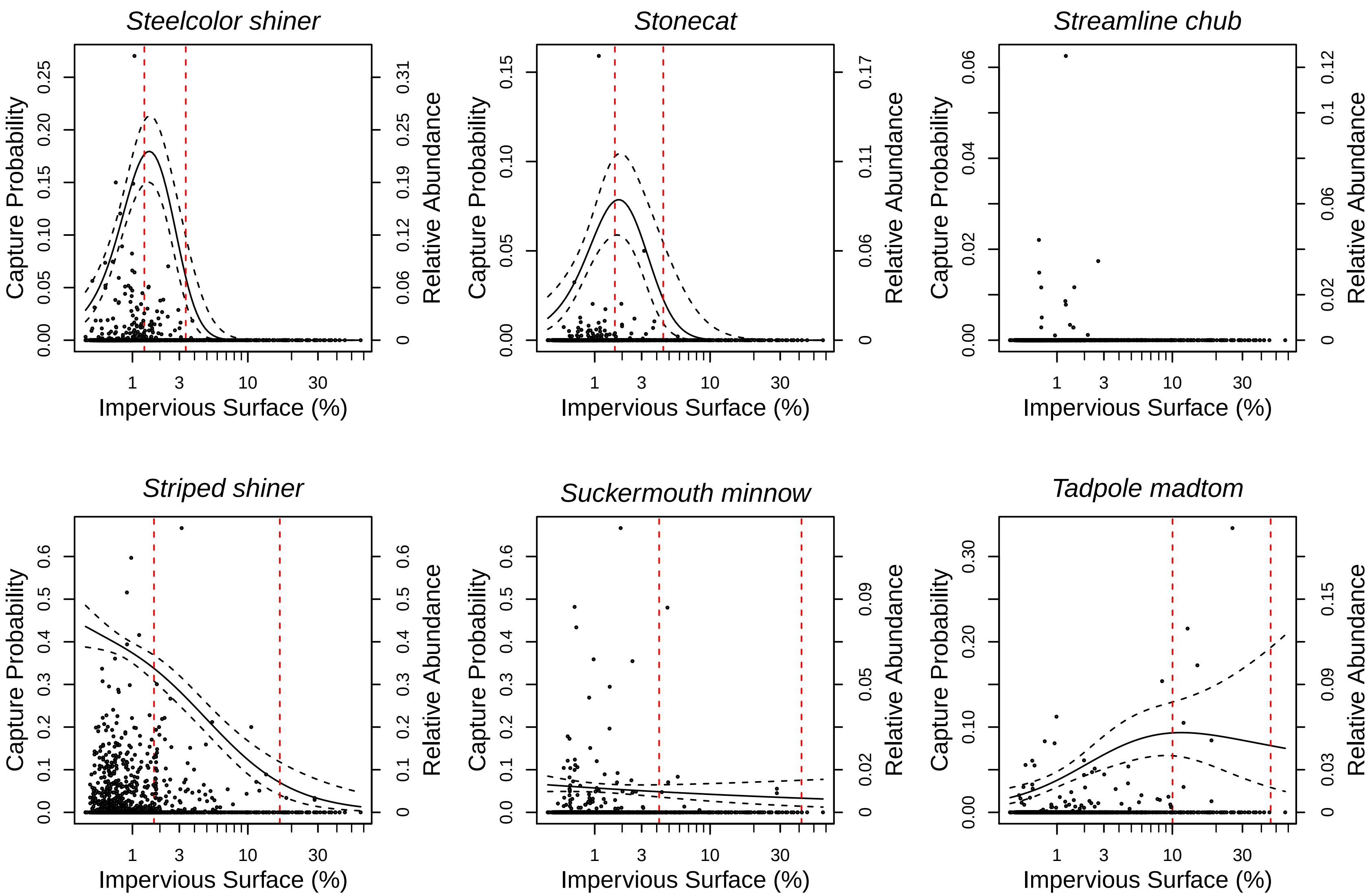
Capture Probability of Fish Taxon Along Impervious Gradient



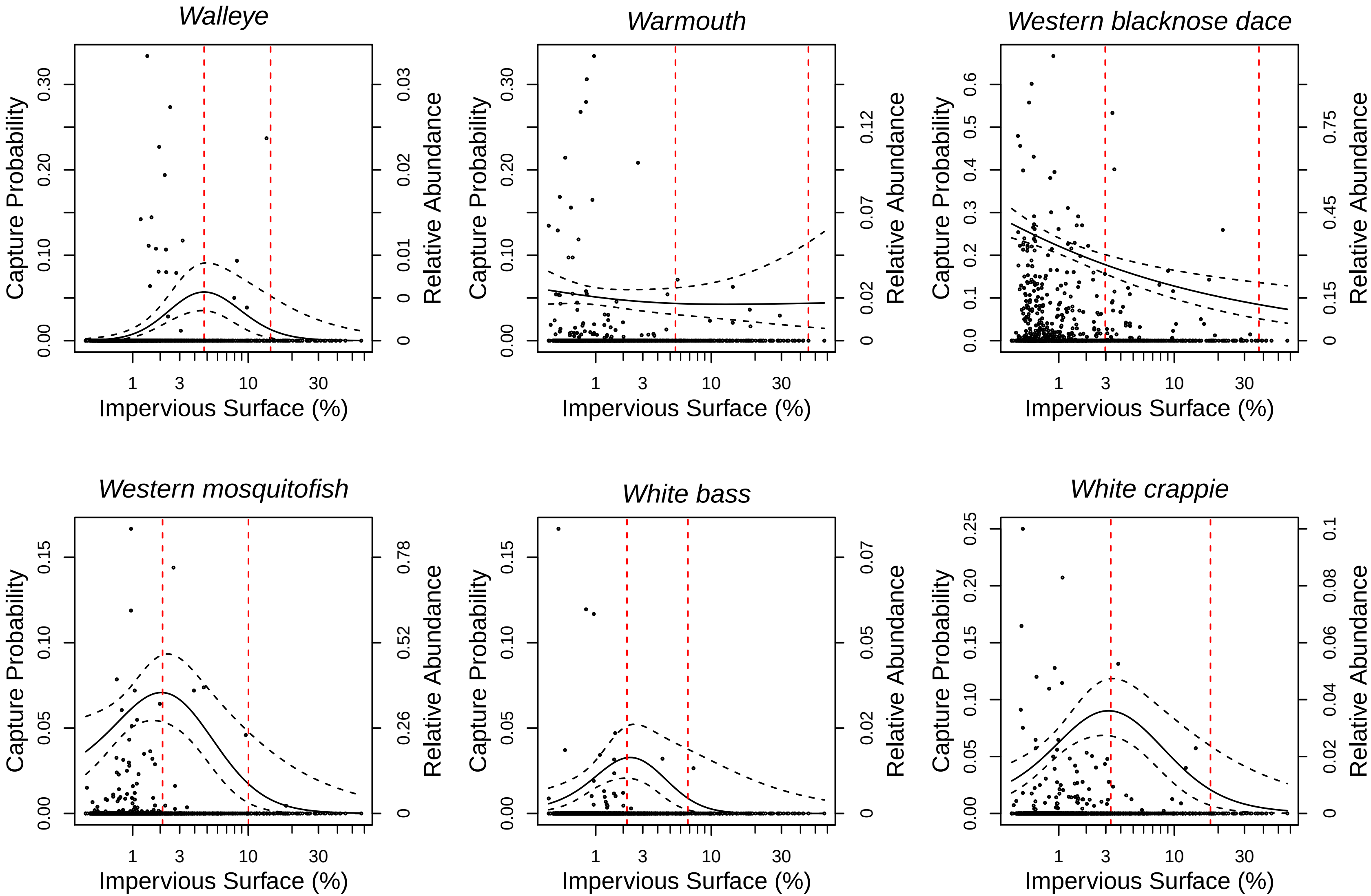
Capture Probability of Fish Taxon Along Impervious Gradient



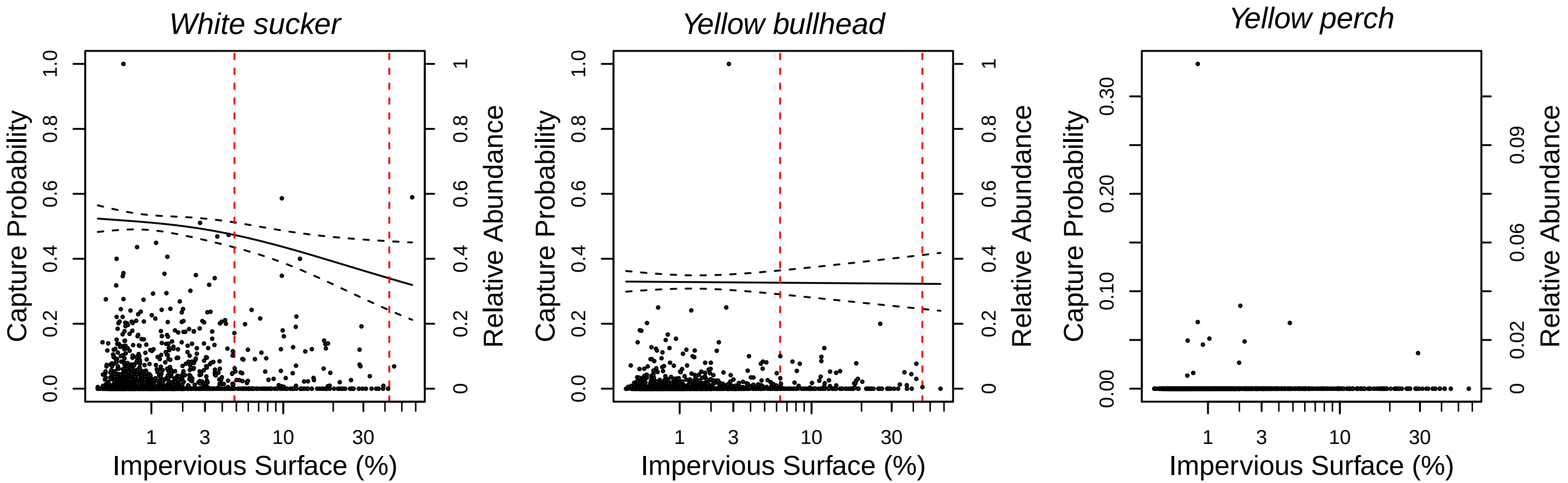
Capture Probability of Fish Taxon Along Impervious Gradient



Capture Probability of Fish Taxon Along Impervious Gradient

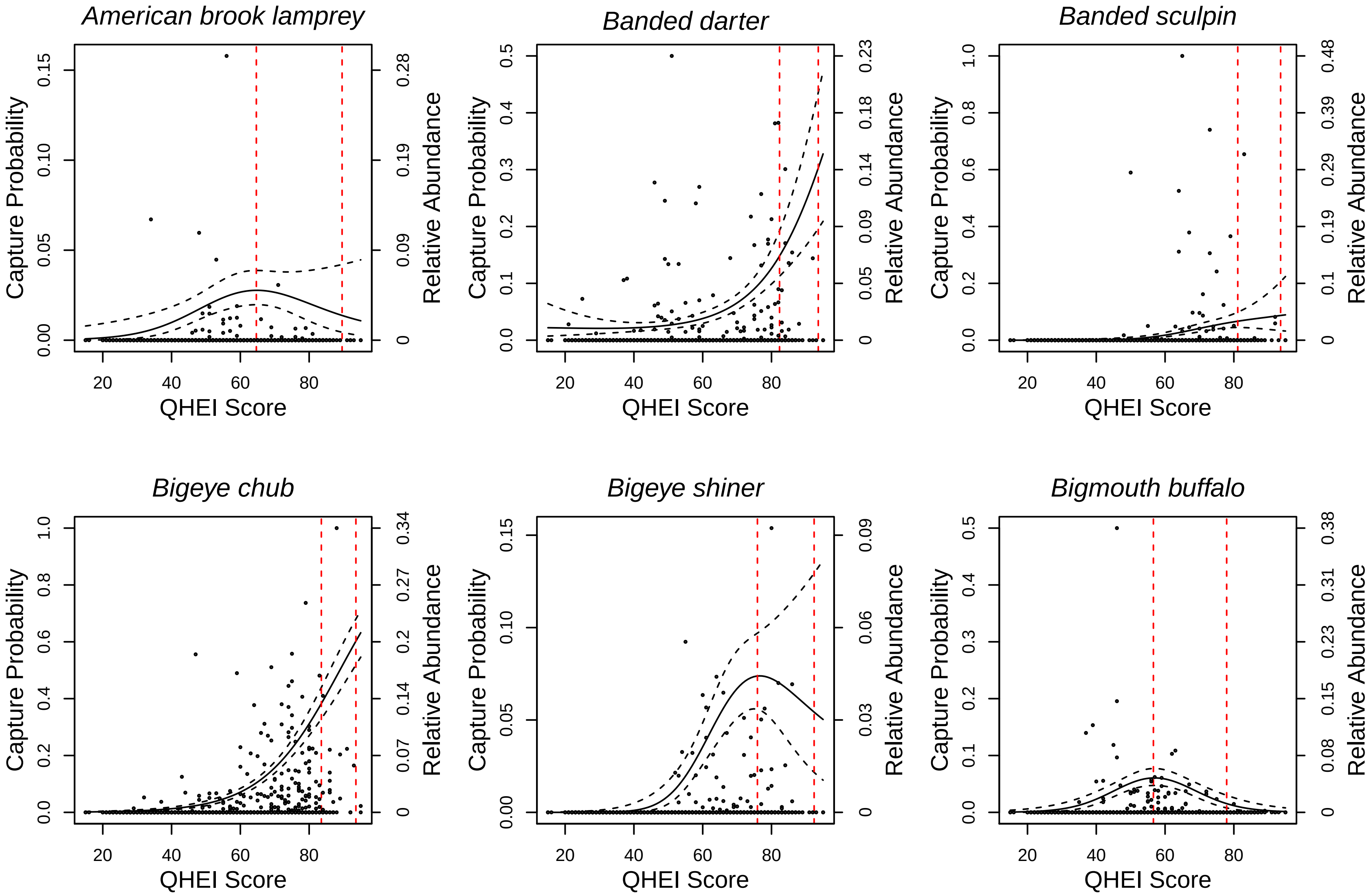


Capture Probability of Fish Taxon Along Impervious Gradient

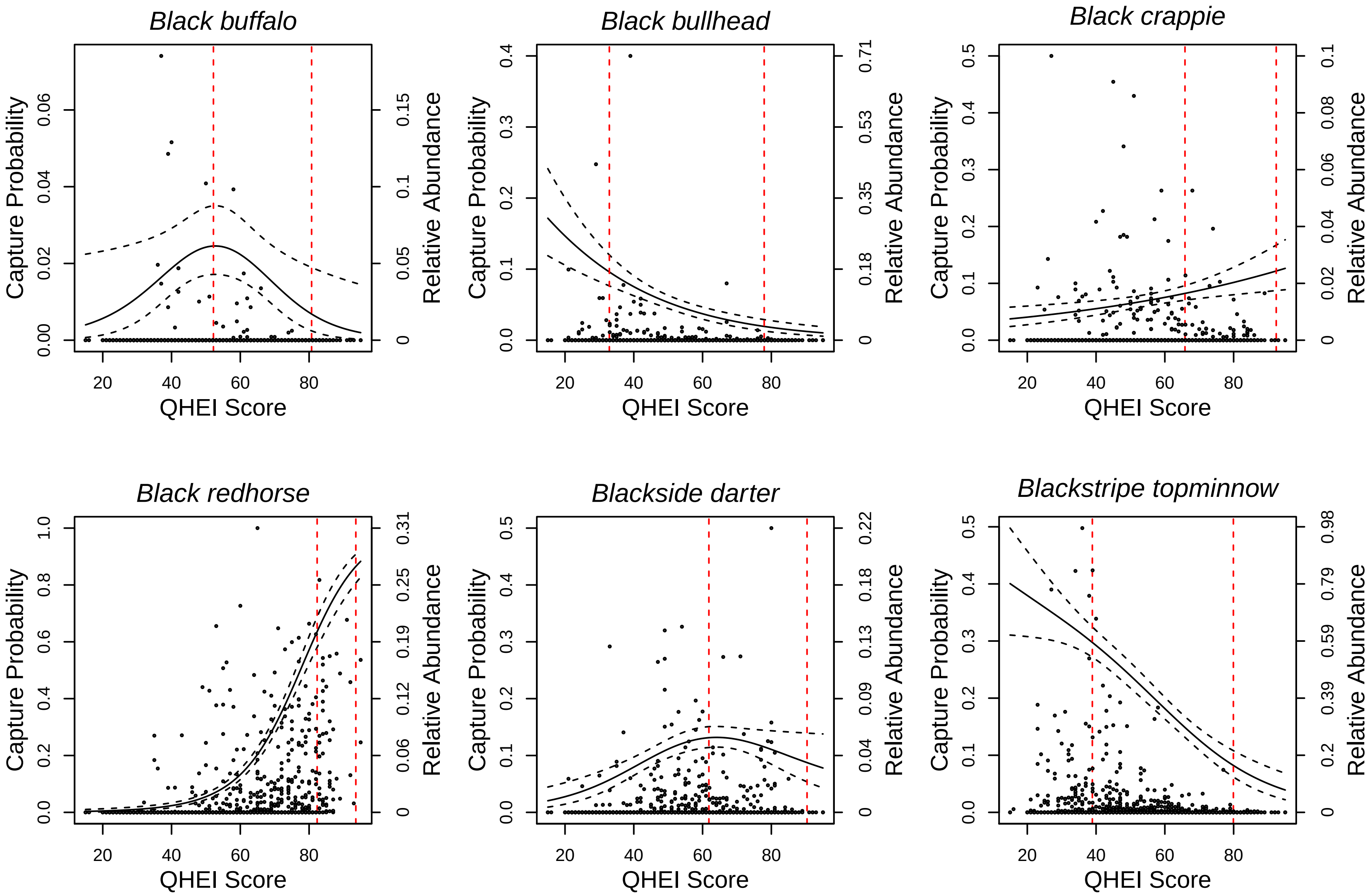


RESPONSES OF FISH TAXA TO THE QUALITATIVE HABITAT EVALUATION INDEX (QHEI)

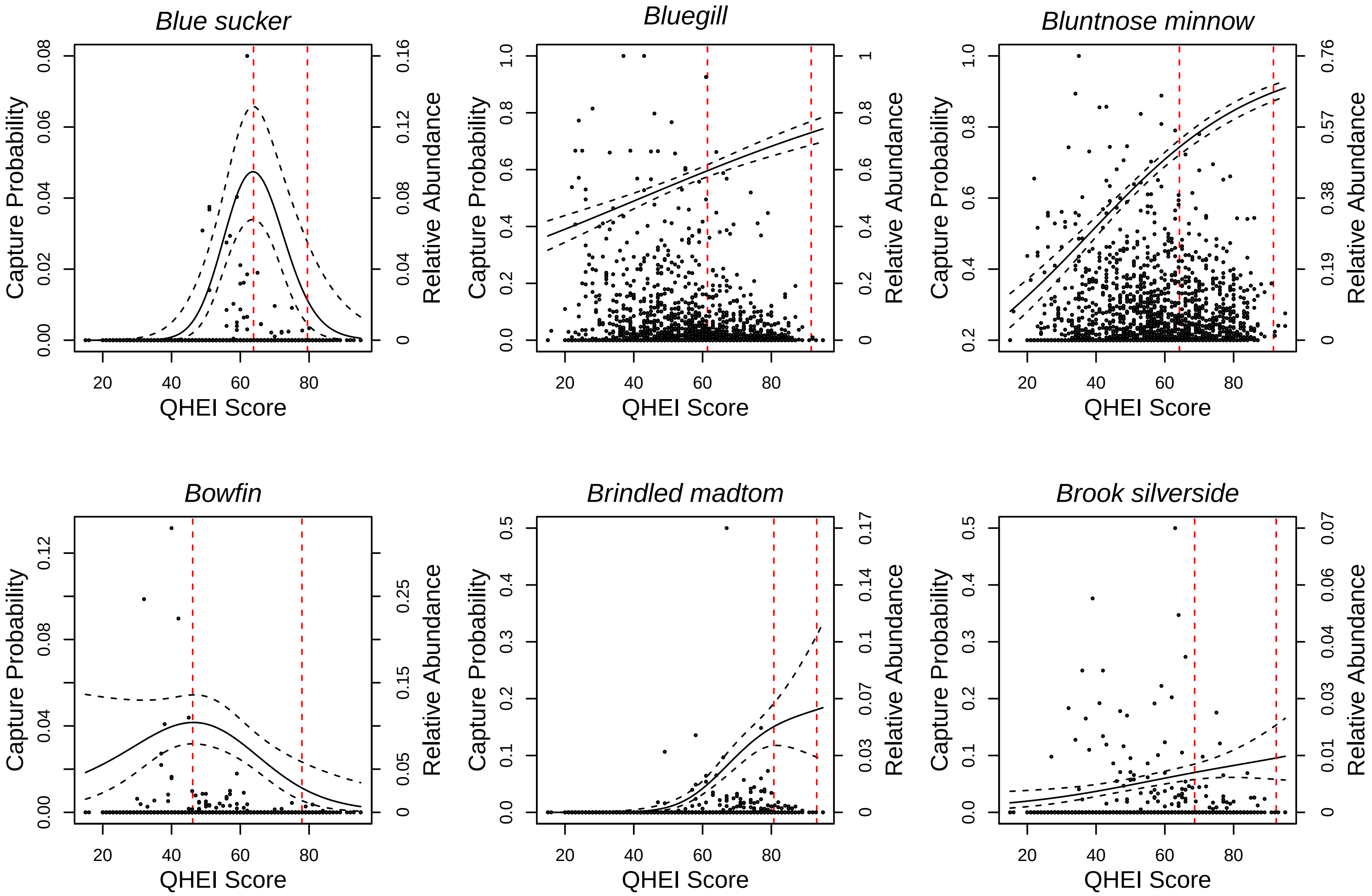
Capture Probability of Fish Taxon Along QHEI Gradient



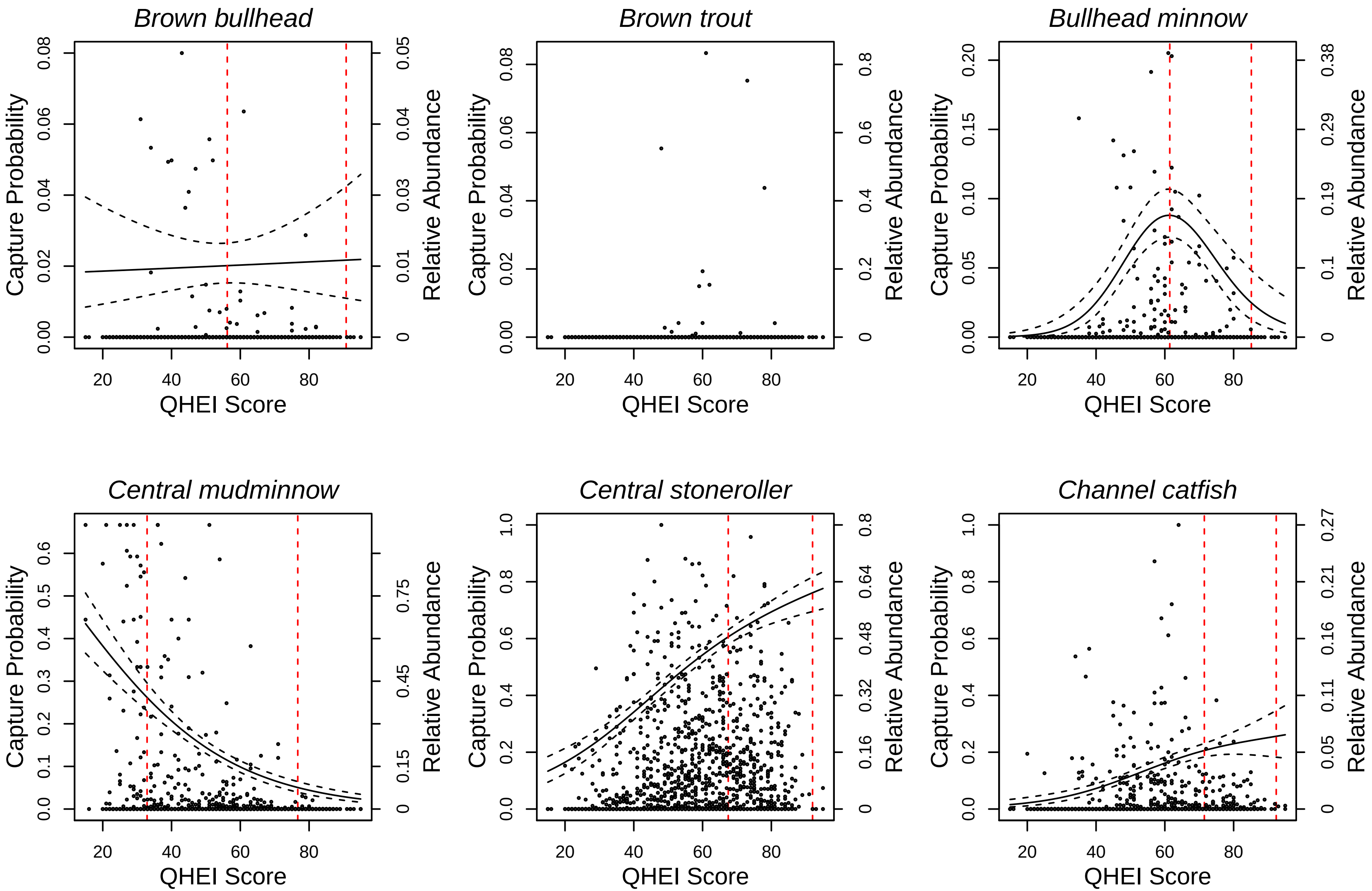
Capture Probability of Fish Taxon Along QHEI Gradient



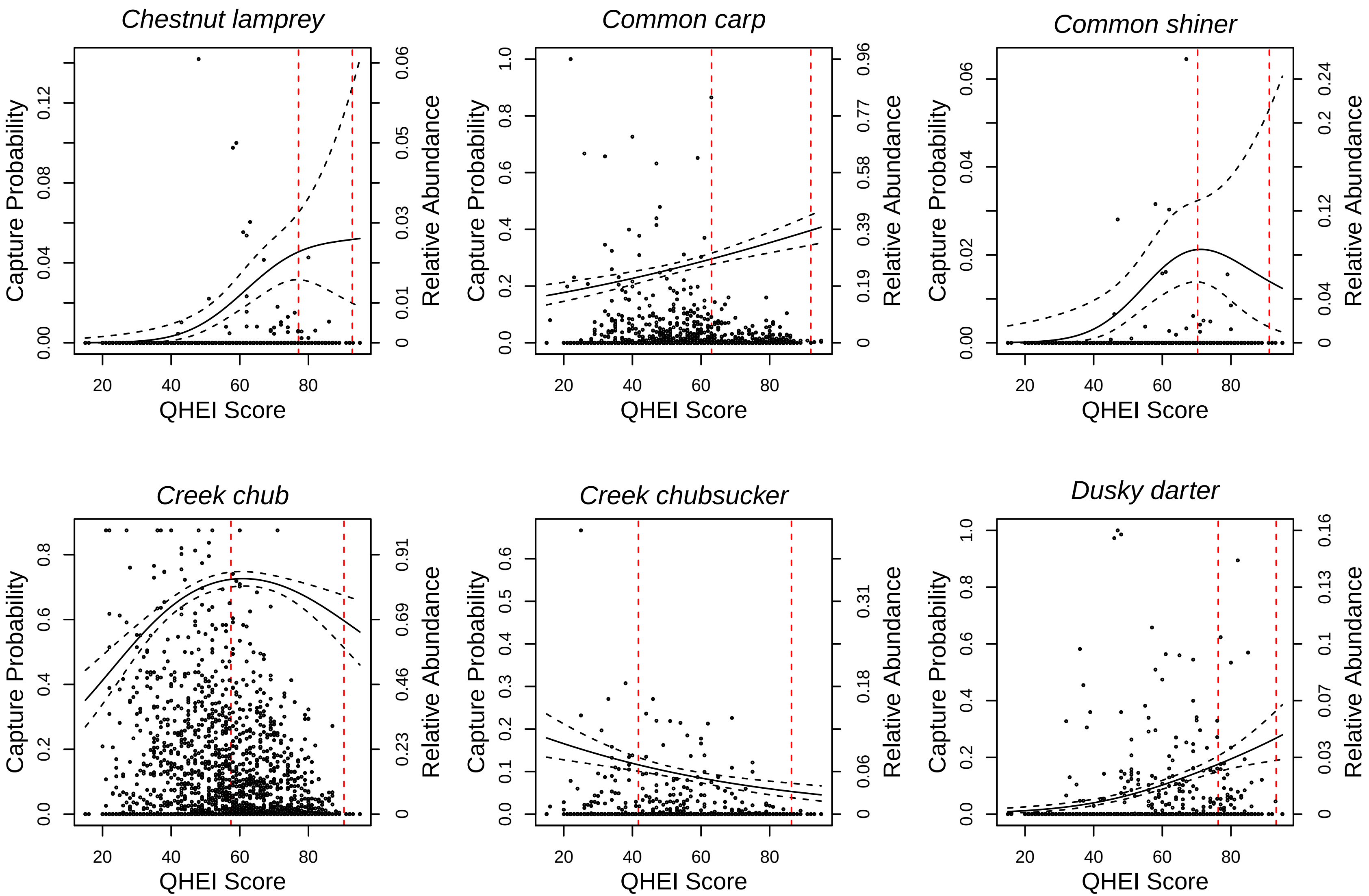
Capture Probability of Fish Taxon Along QHEI Gradient



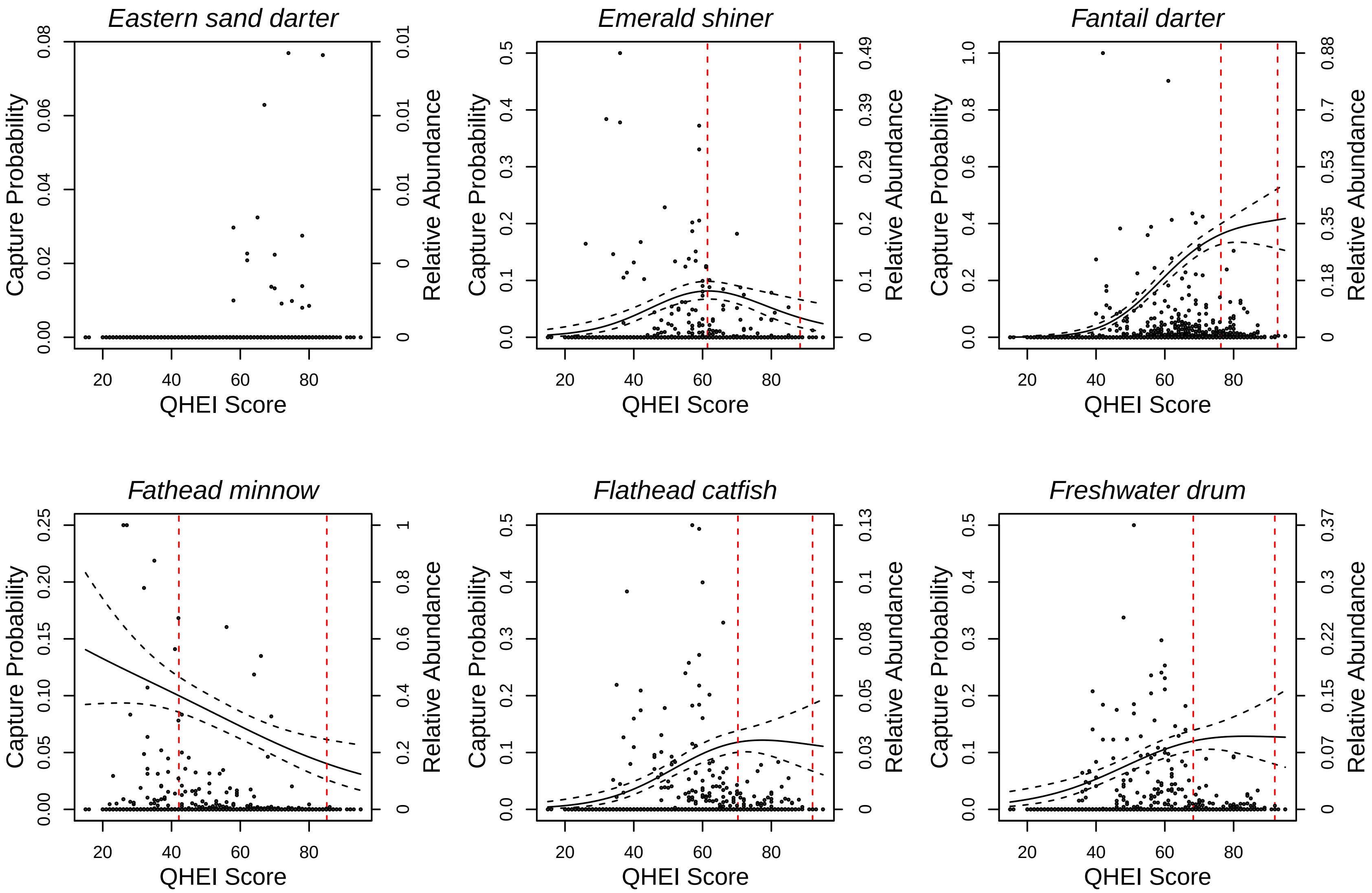
Capture Probability of Fish Taxon Along QHEI Gradient



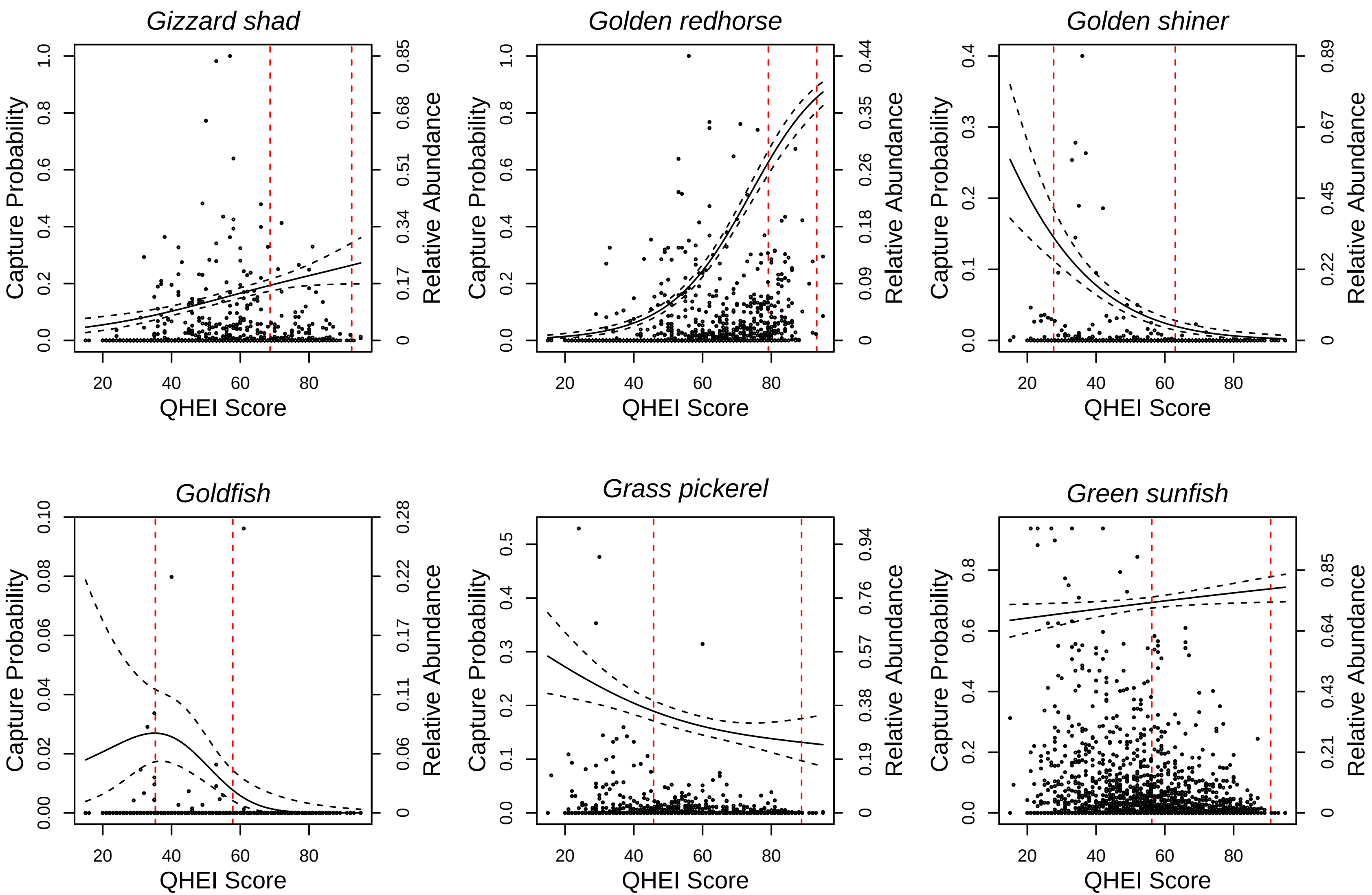
Capture Probability of Fish Taxon Along QHEI Gradient



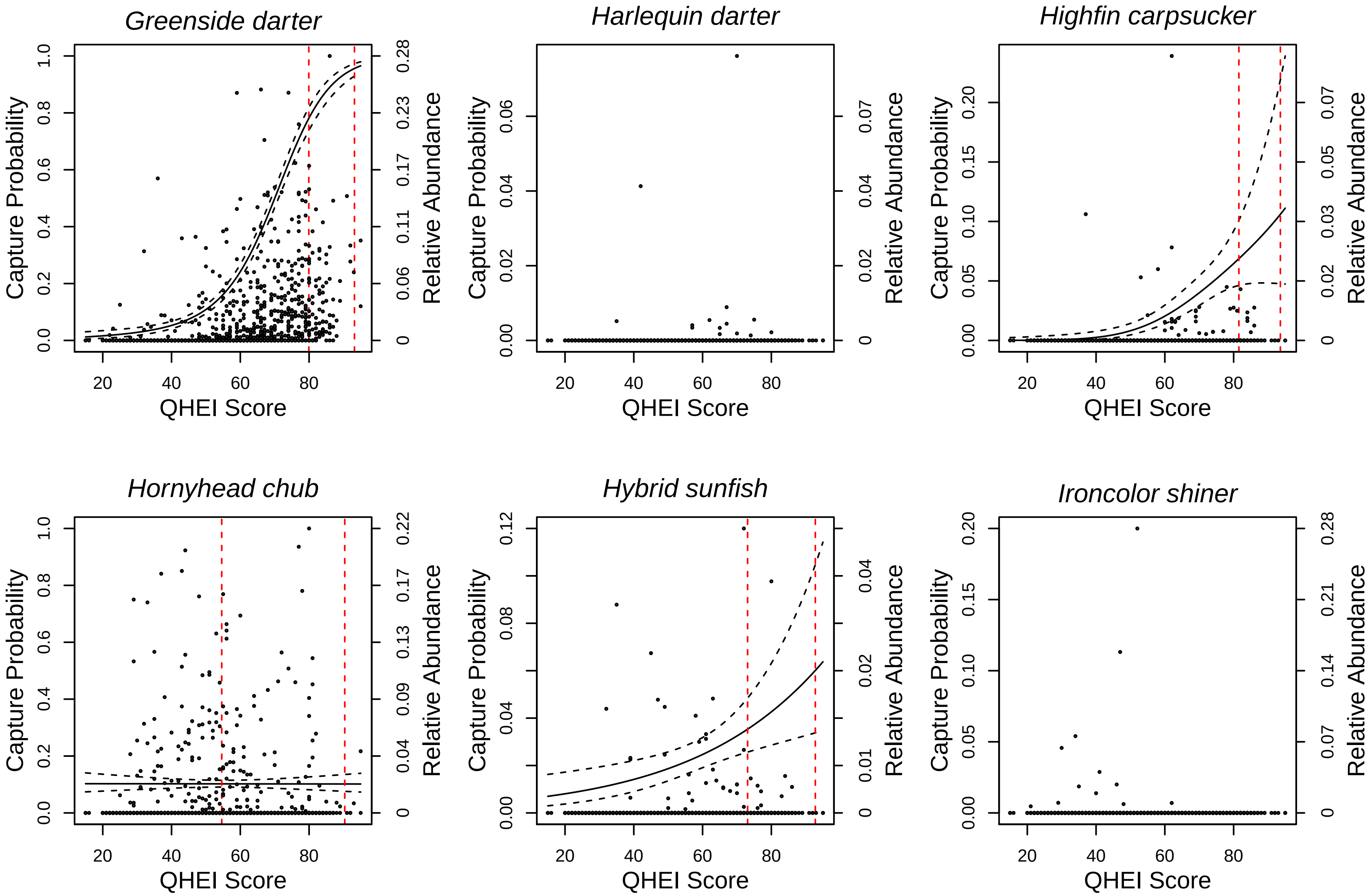
Capture Probability of Fish Taxon Along QHEI Gradient

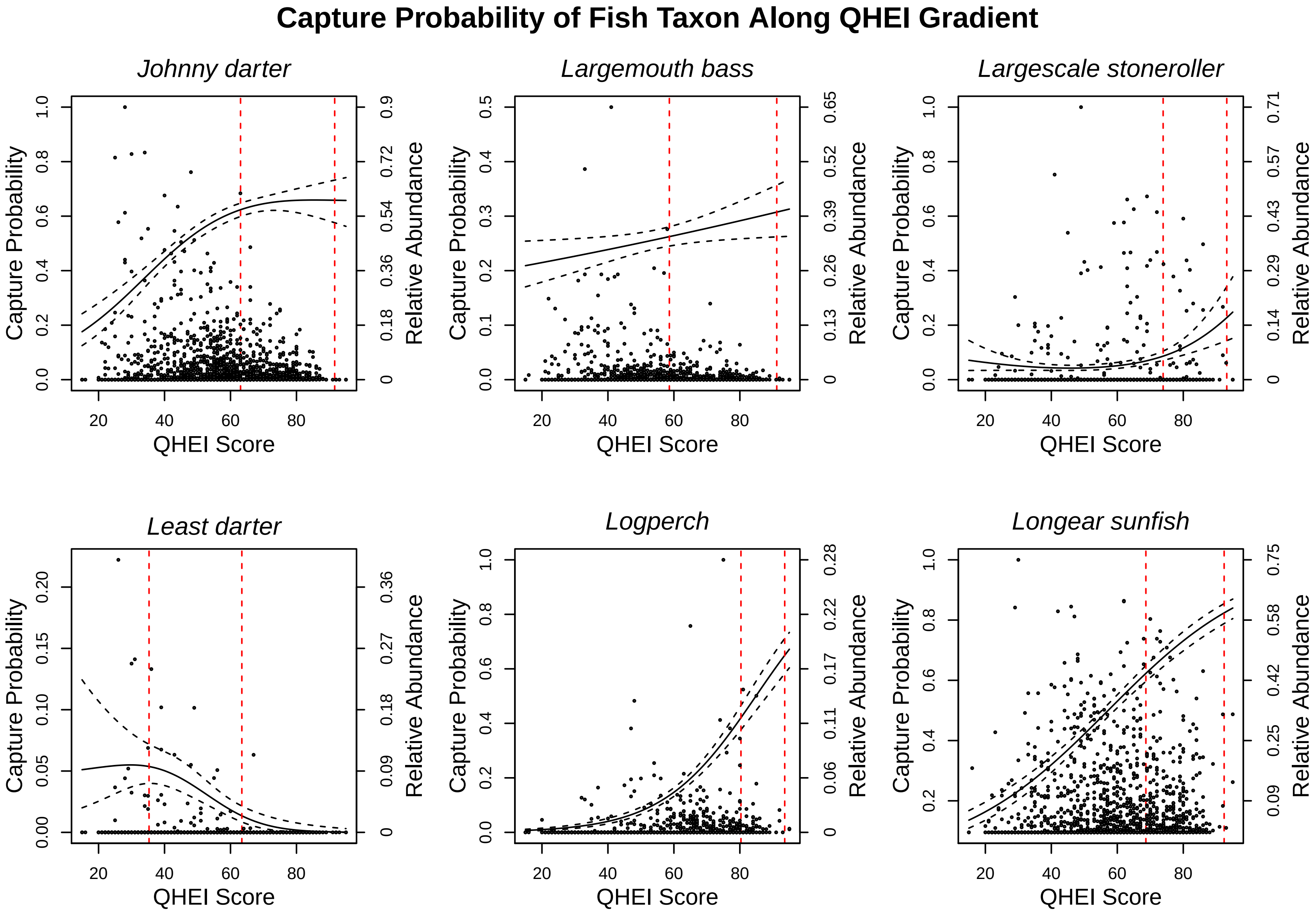


Capture Probability of Fish Taxon Along QHEI Gradient

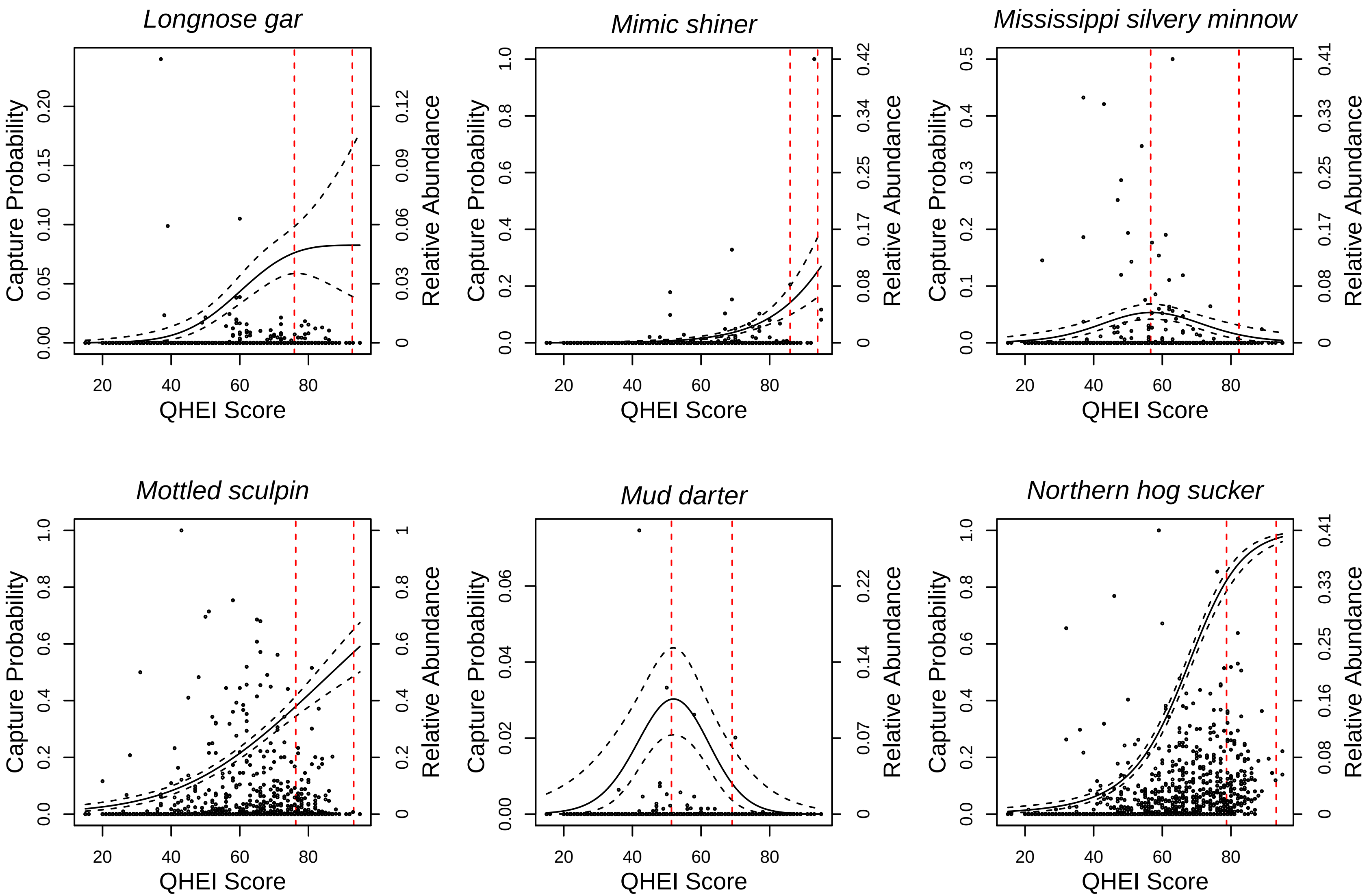


Capture Probability of Fish Taxon Along QHEI Gradient

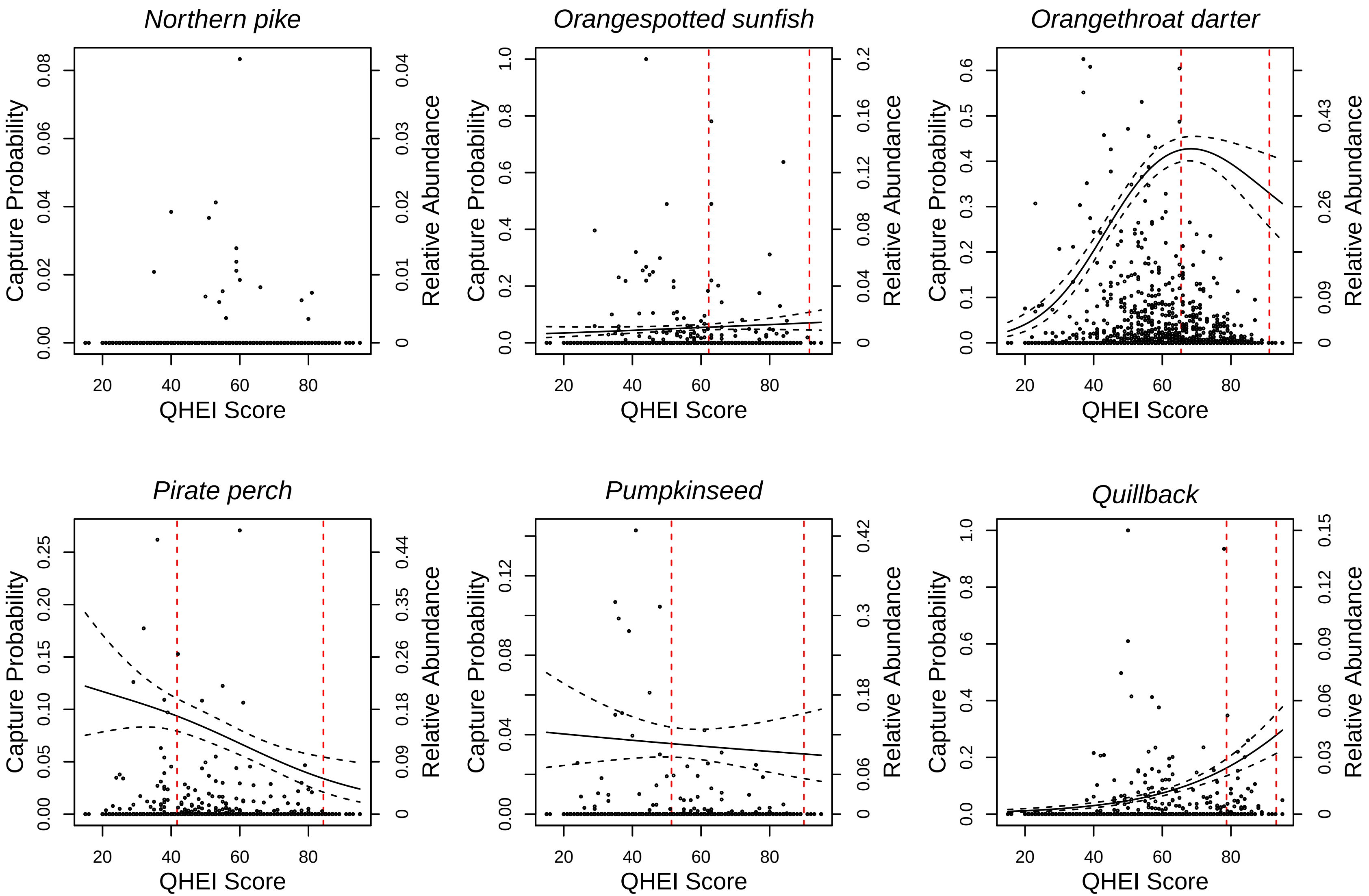



Capture Probability of Fish Taxon Along QHEI Gradient
Johnny darter
Largemouth bass
Largescale stoneroller
Least darter
Logperch
Longear sunfish
Capture Probability
Relative Abundance
QHEI Score

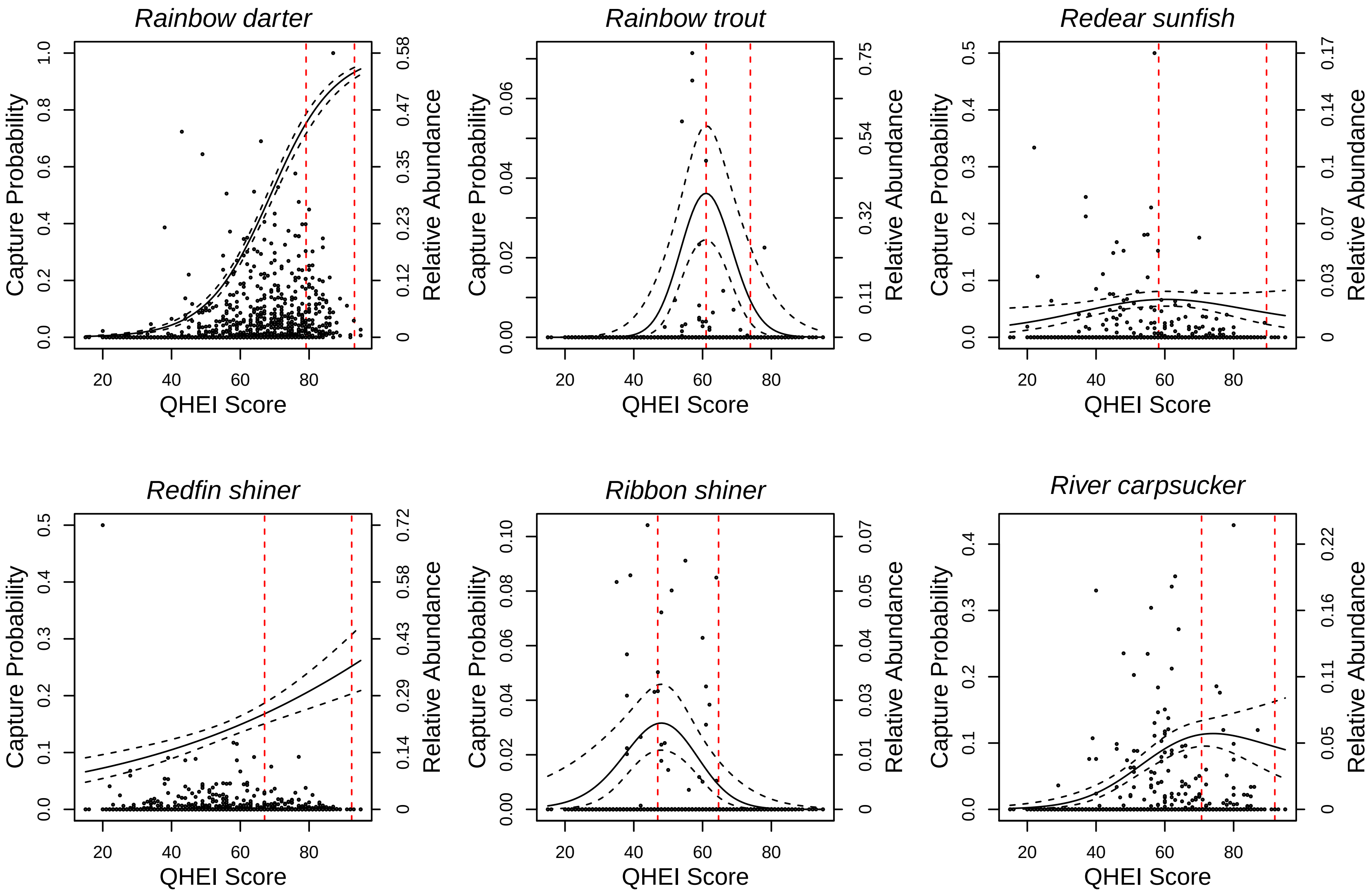
Capture Probability of Fish Taxon Along QHEI Gradient



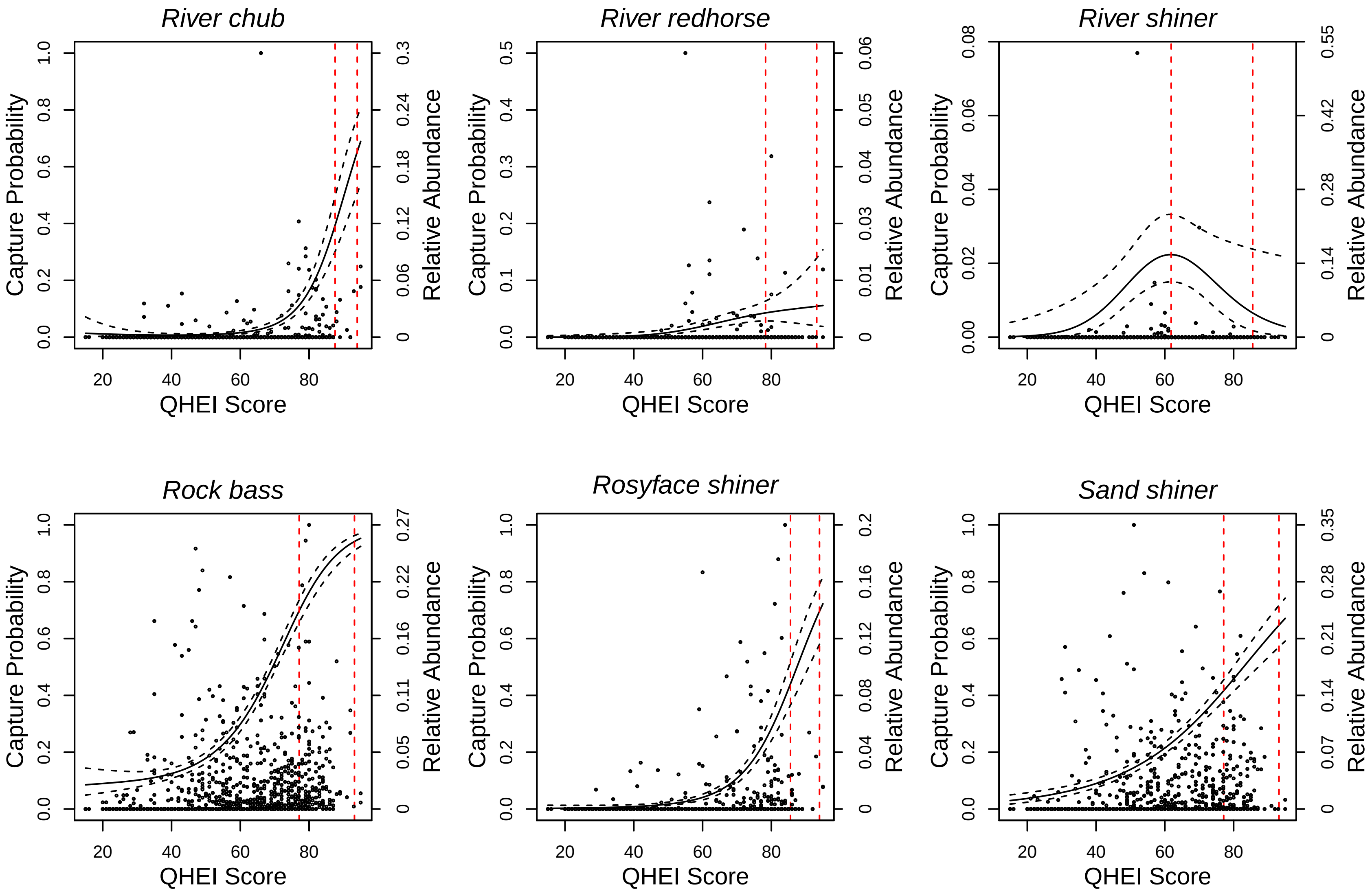
Capture Probability of Fish Taxon Along QHEI Gradient



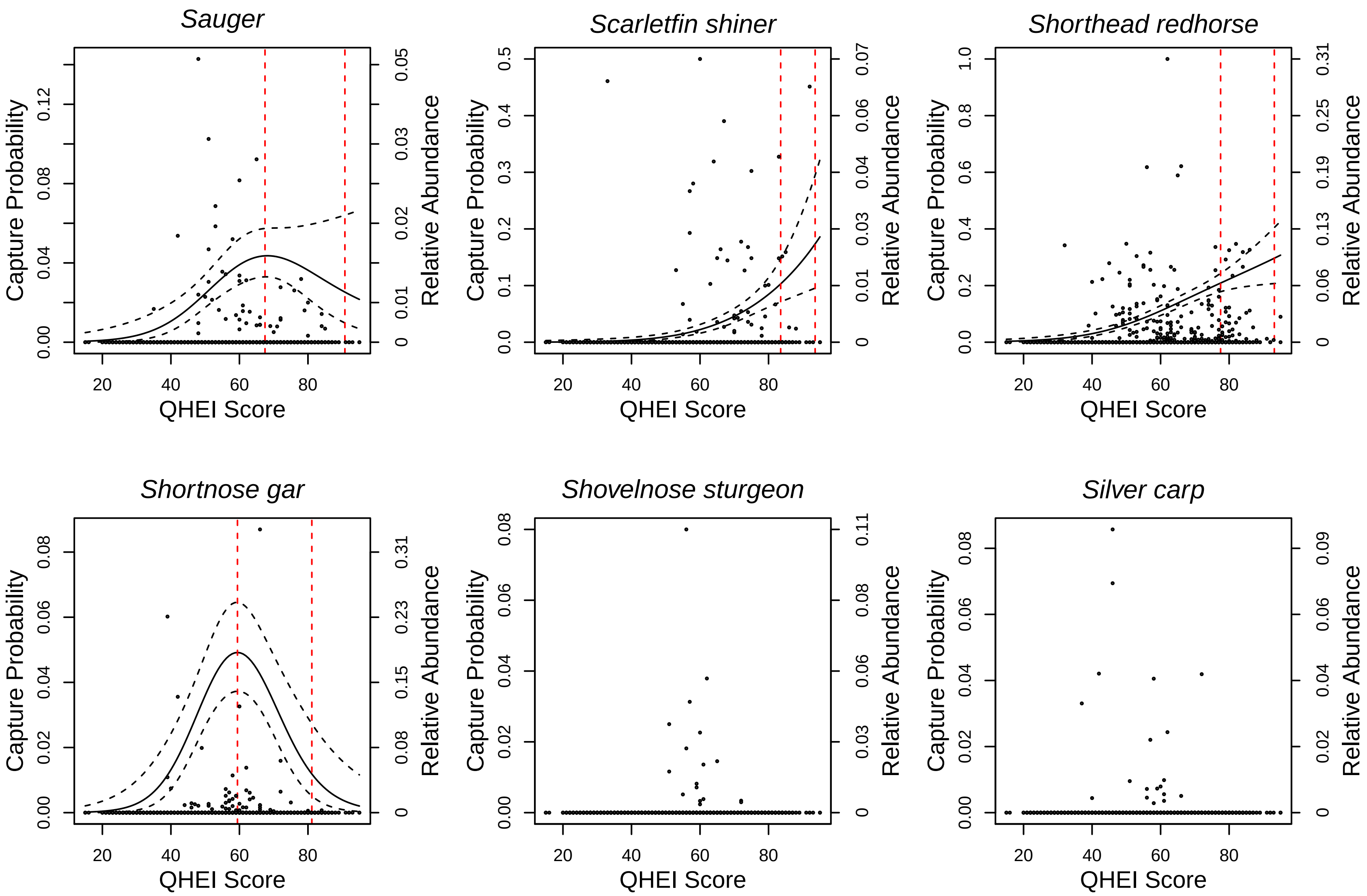
Capture Probability of Fish Taxon Along QHEI Gradient



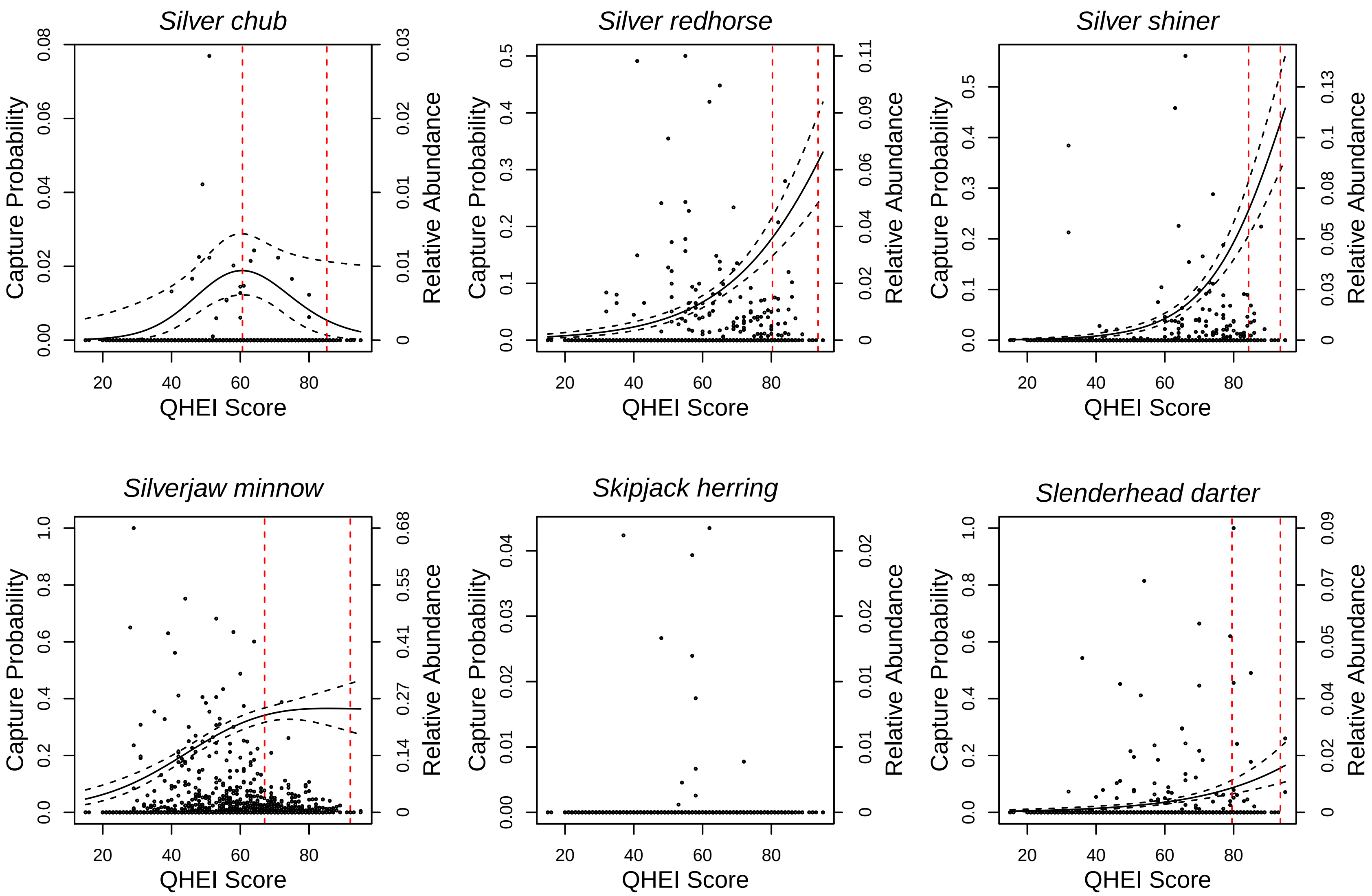
Capture Probability of Fish Taxon Along QHEI Gradient



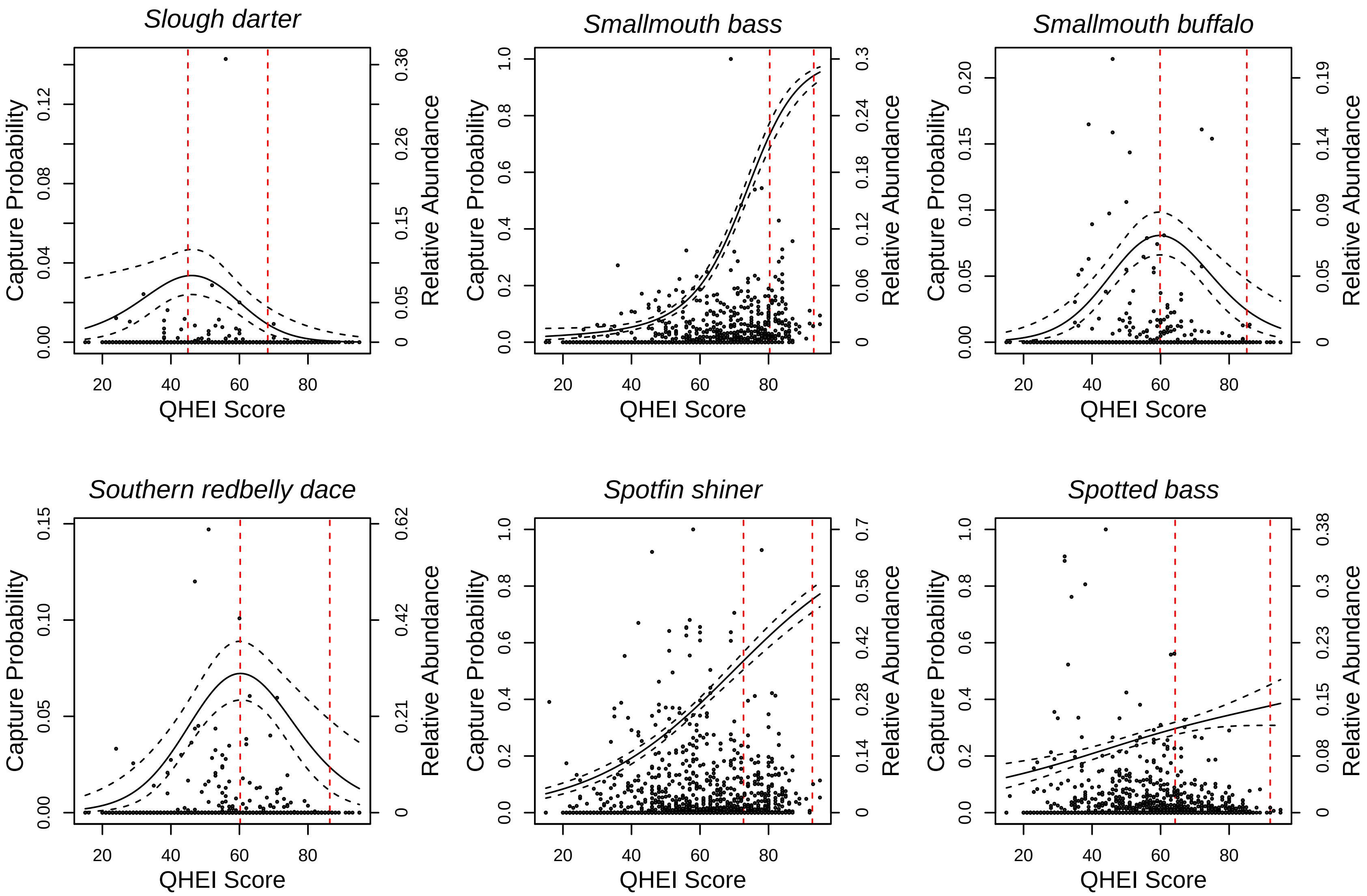
Capture Probability of Fish Taxon Along QHEI Gradient



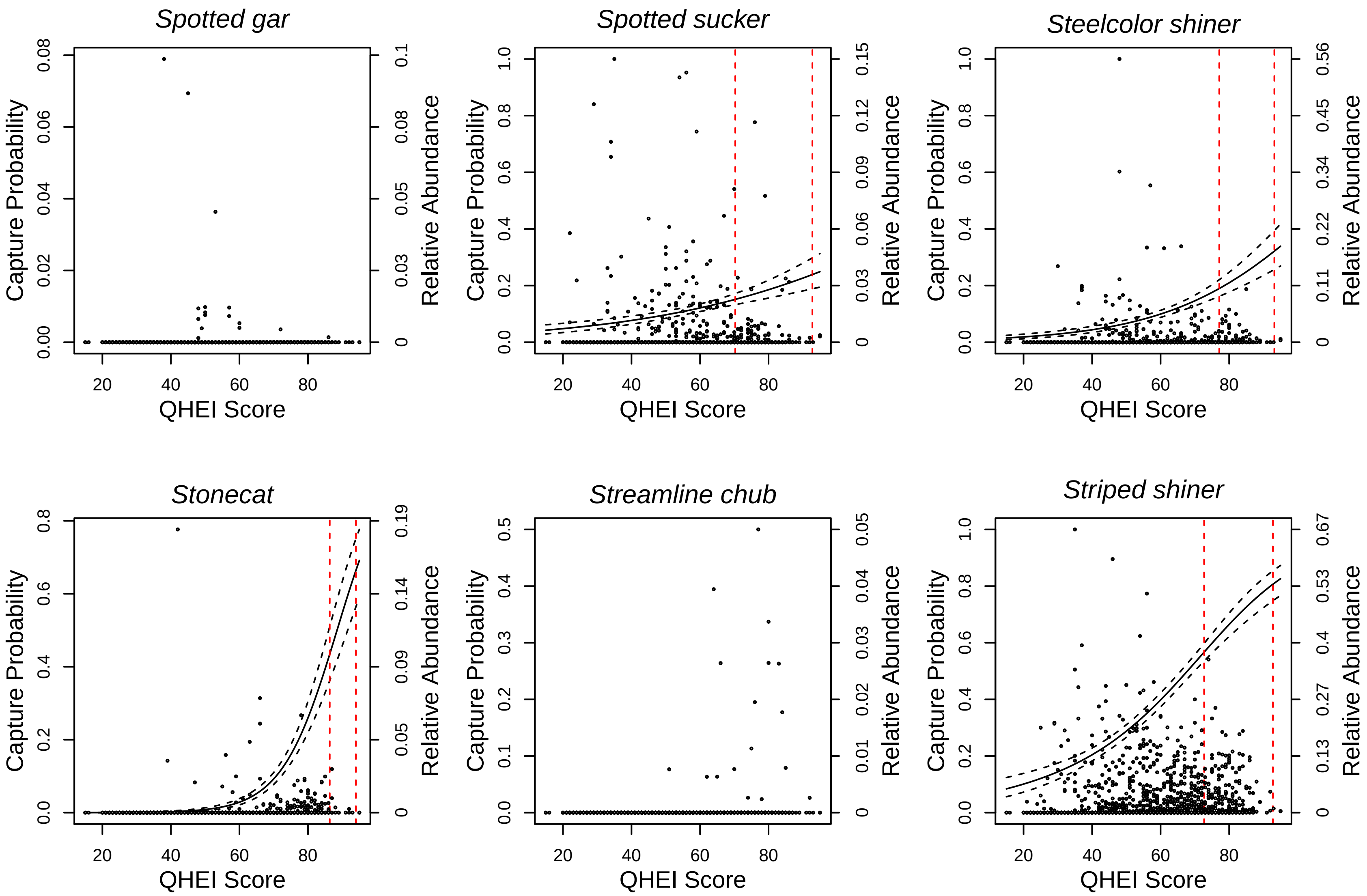
Capture Probability of Fish Taxon Along QHEI Gradient



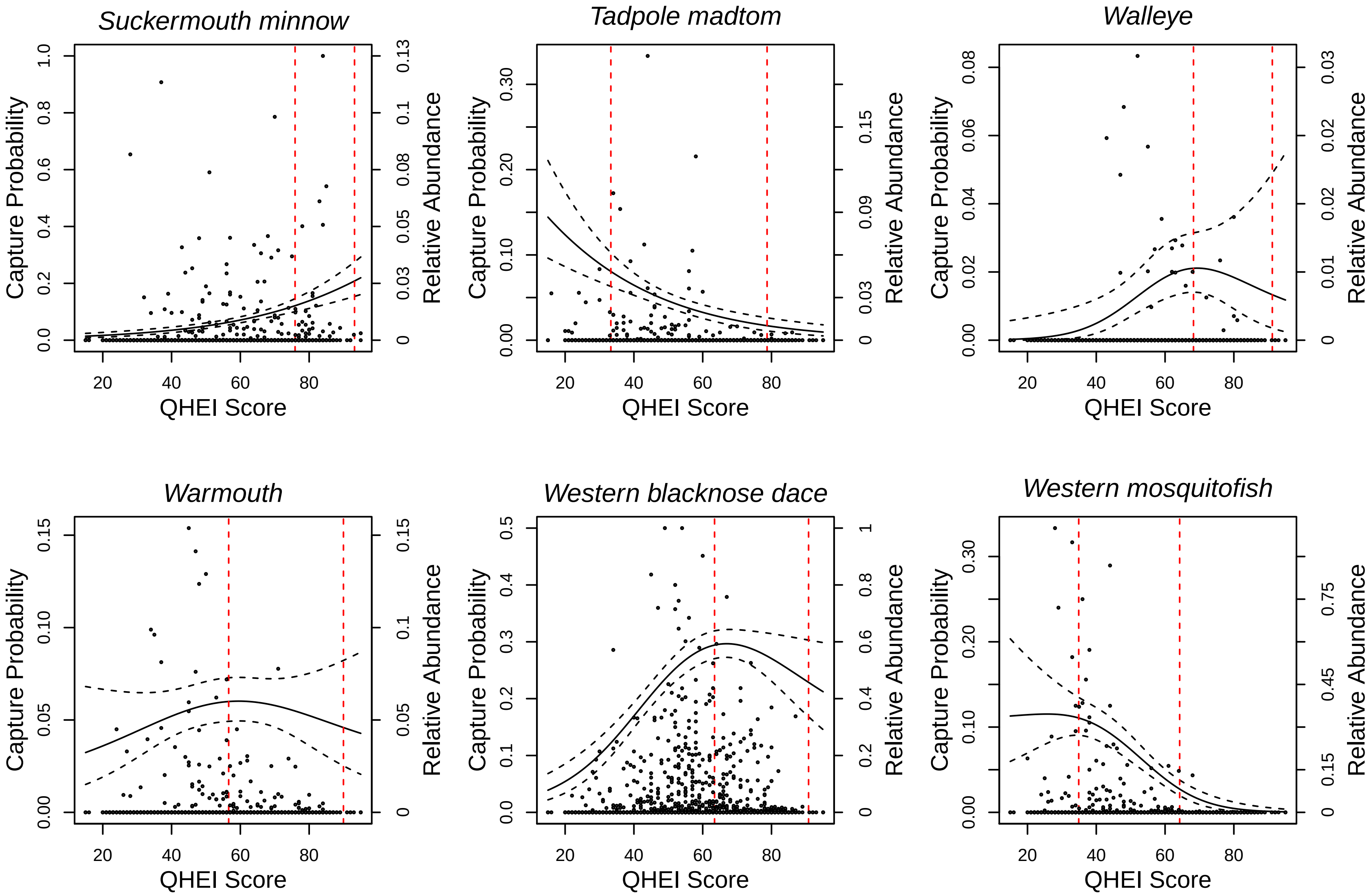
Capture Probability of Fish Taxon Along QHEI Gradient



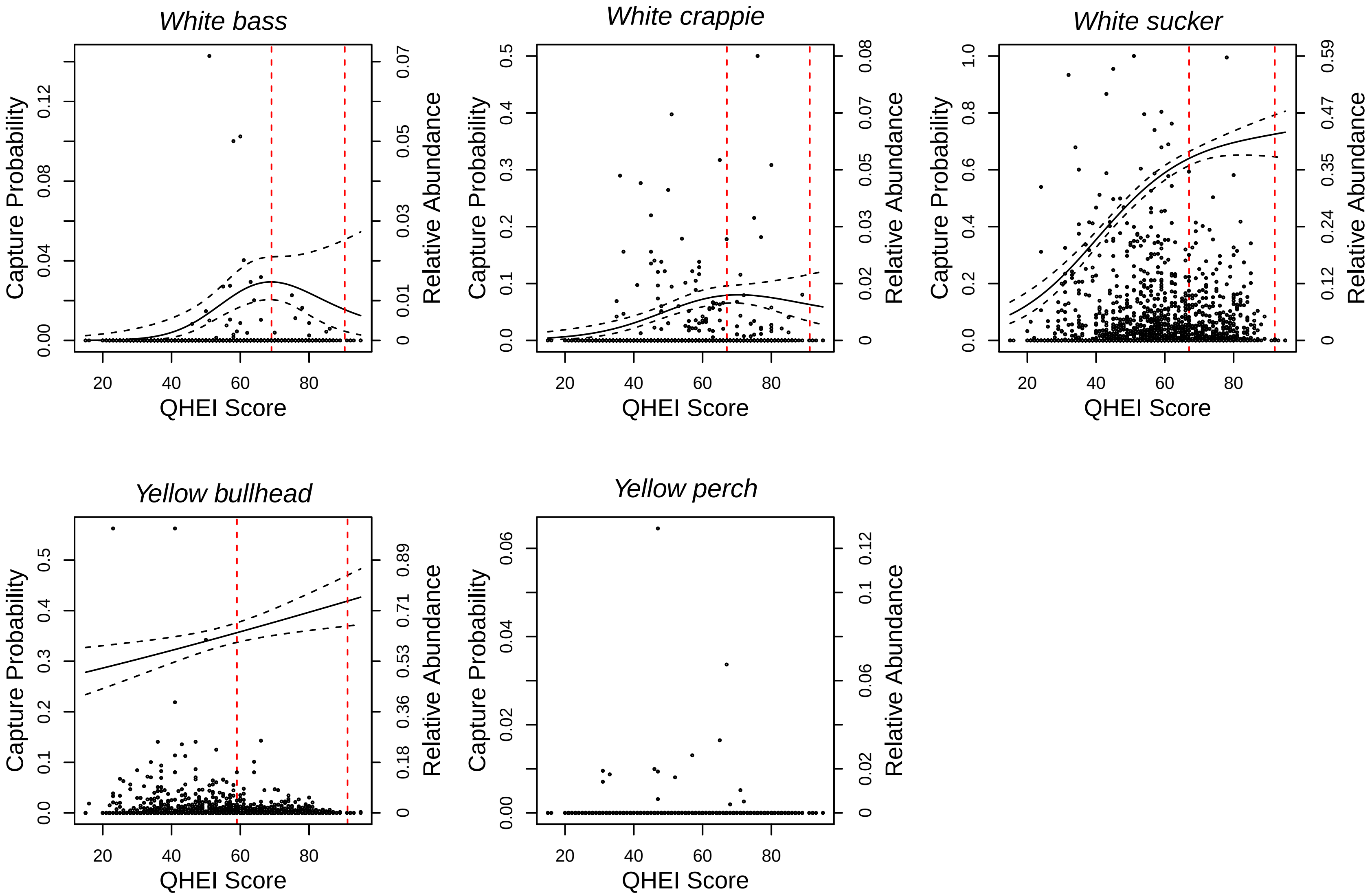
Capture Probability of Fish Taxon Along QHEI Gradient



Capture Probability of Fish Taxon Along QHEI Gradient



Capture Probability of Fish Taxon Along QHEI Gradient



Appendix D

Sample Worksheet

Figure D1. Example of a fish worksheet that was used when making BCG level assignments.

ExerciseID	Samp0001	**Best Tier**		x	**Assigned Tier**	**Reasoning**
Collection Date	2007-06-20	**Median Tier**	x	x		
Collection Method	Backpack	**Worst Tier**		x		

TAXA SUMMARY

BCG Attribute	Number of Taxa	Count	Biomass	Pct Taxa	Pct Density	Pct Biomass
1	0	0	0.0	0%	0%	0%
2	1	4	13.0	9%	1%	1%
3	2	123	192.5	18%	25%	14%
4	5	288	525.0	45%	59%	39%
5	3	72	623.0	27%	15%	46%
6	0	0	0.0	0%	0%	0%
6i	0	0	0.0	0%	0%	0%
x	0	0	0.0	0%	0%	0%
Total	*11*	*487*	*1,353.5*	*100%*	*100%*	*100%*

TAXA LIST

BCG Attribute	Common Name	Scientific Name	Count	Biomass	Family	TaxaMap
5	white sucker	Catostomus commersoni	19	359	Catostomidae	map
4	central stoneroller	Campostoma anomalum	30	85	Cyprinidae	map
2	redside dace	Clinostomus elongatus	4	13	Cyprinidae	map
4	silverjaw minnow	Ericymba buccata	1	1	Cyprinidae	map
3	silver shiner	Notropis photogenis	2	0.5	Cyprinidae	map
3	southern redbelly dace	Phoxinus erythrogaster	121	192	Cyprinidae	map
5	bluntnose minnow	Pimephales notatus	9	20	Cyprinidae	map
4	western blacknose dace	Rhinichthys obtusus	191	352	Cyprinidae	map
5	creek chub	Semotilus atromaculatus	44	244	Cyprinidae	map
4	johnny darter	Etheostoma nigrum	34	45	Percidae	map
4	orangethroat darter	Etheostoma spectabile	32	42	Percidae	map

STATION AND SAMPLE CHARACTERISTICS

StationID		StationID
ActivityID		VisitNum
Latitude	39.66192152	latitude
Longitude	-84.88023297	longitude
Date	2007-06-20	VisitDate
Waterbody Name		WaterbodyName
Gradient	29.7	GRADIENT
HUC 12	50800030714	HUC_12
Strahler	2	ST_ORDER
Ecoregion Number (L3)	55	US_L3CODE
Ecoregion Name (L3)	Eastern Corn Belt Plains	US_L3NAME
QHEI Total Score (New)		QHEI_TOTAL_SCORE_New
QHEI Total Score (Historical)	71	QHEI_TOTAL_SCORE_Historical
DO	7.99	DO
Flow	0.00	Flow
pH (Field)	8.34	pH (Field)
Specific Conductance (Field)	566	Specific Conductance (Field)
Temperature	22.1	Temperature
Turbidity	22.7	Turbidity
Watershed area, mi2	3.3	W_AREA_MI
% DELT anomalies	0.0	pcDELT

ParticipantAssignments

Participant	Score	Reasons
Todd Davis		
Charlie Morris		
Paul McMurray		
Jim Stahl		
Ali Meils		
Kevin Crane		
Brant Fisher		
Kayla Werbianskyj		
Reid Morehouse		
Mark Pyron		
Kevin Gaston		
Drew Holloway		
Jamie Lau		
Aubrey Bunch		
Ed Dobrowolski		
Stacey Sobat		
Chris Yoder		

Appendix E

BCG Level Assignments

Table E1 summarizes the number of fish samples that were assessed during the BCG exercise. The samples were assessed using the scoring scale shown in Figure E1. BCG level assignments (from panelists and the BCG models) for the calibration (cal) and confirmation (confirm) samples are summarized in Tables E2 through E11 -

- Tables E2 (cal) & E3 (confirm) – Eastern Corn Belt Plains (ecoregion 55) + Interior Plateau (ecoregion 71)
- Tables E4 (cal) & E5 (confirm) – Interior River Lowlands (ecoregion 72)
- Tables E6 (cal) & E7 (confirm) – Central Corn Belt Plains (ecoregion 54)
- Tables E8 (cal) & E9 (confirm) - Southern Michigan/Northern Indiana Drift Plains (ecoregion 56)
- Tables E10 (cal) & E11 (confirm) – Large Rivers

Table E1. Number of calibration and confirmation fish samples that were assessed in each stream class, organized by BCG level (group consensus).

Stream Class	BCG level	Calibration		Confirmation	
		< 20 mi2	≥ 20 mi2	< 20 mi2	≥ 20 mi2
Eastern Corn Belt Plains + Interior Plateau	2	0	4	0	1
	3	2	16	3	1
	4	12	21	1	1
	5	5	2	0	0
	6	1	4	1	1
	Totals	***20***	***47***	***5***	***4***
Interior River Lowlands	2	0	0	0	0
	3	0	3	0	2
	4	5	5	2	1
	5	2	6	2	1
	6	1	0	1	1
	Totals	***8***	***14***	***5***	***5***
Central Corn Belt Plains	2	0	0	0	0
	3	2	5	1	1
	4	12	8	4	2
	5	1	4	0	3
	6	4	2	0	0
	Totals	***19***	***19***	***5***	***6***
Southern Michigan/ Northern Indiana Drift Plains	2	0	0	0	0
	3	0	6	0	2
	4	7	12	2	1
	5	6	2	4	1
	6	2	0	0	0
	Totals	***15***	***20***	***6***	***4***

Table E1 continued…

Stream Class	BCG level	Calibration	Confirmation
Large Rivers	2	2	3
	3	5	1
	4	14	4
	5	4	1
	6	0	0
	Totals	***25***	***9***

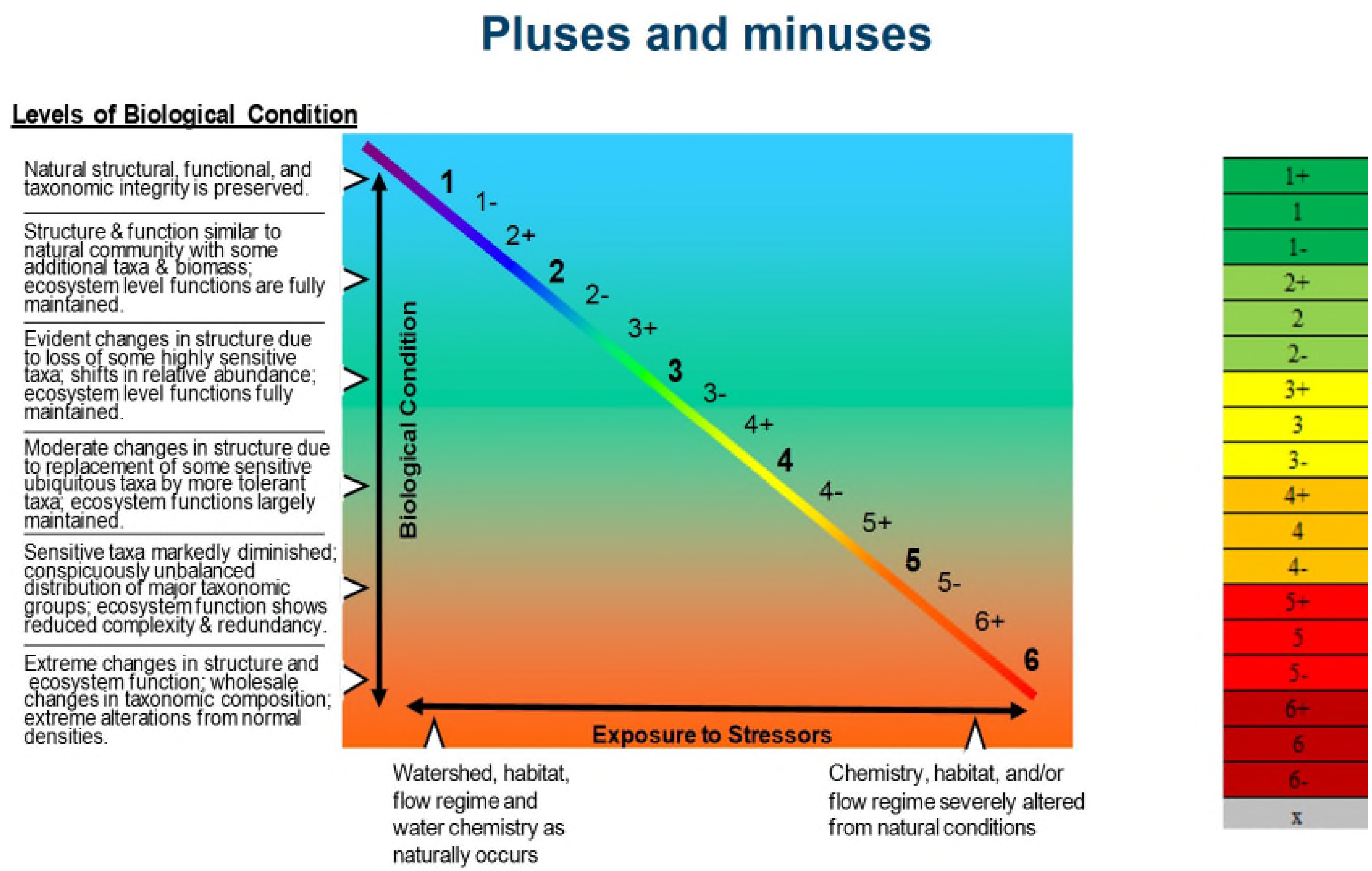


Figure E1. Scoring scale used by panelists when assessing calibration and confirmation samples.

Eastern Corn Belt Plains + Interior Plateau

Table E2. BCG level assignments and sample information for Eastern Corn Belt + Interior Plateau fish samples that were assessed during the calibration exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 4 (0.60)/Secondary 5 (0.40) means that the model assigns the sample to BCG level 4, with a 0.60 probability of membership in BCG level 4 and a 0.40 probability of membership in BCG level 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WAW040-0135	Tributary of South Fork Wildcat Creek	AA21663	Samp0506	2004-08-09	Longline	1.5	4	4 (1.00)	--	
WPA-01-0009	Patoka River	AB08450	Samp0477	2012-07-16	Longline	1.6	4	4 (0.60)	5 (0.40)	
WEM020-0030	Rush Branch	AA46678	Samp0242	2007-07-31	Longline	2.3	5+	4 (0.59)	5 (0.41)	model 1/2 level better
GMW070-0096	Hanna Creek	AA47246	Samp0001	2007-06-20	Backpack	3.3	4	4 (1.00)	--	
WAW040-0101	Mott Ditch	AA21323	Samp1061	2004-08-10	Longline	4.1	6	6 (1.00)	--	
WEM050-0036	Sugar Creek	AA48776	Samp0365	2007-07-25	Longline	5.1	4-	4 (0.90)	3 (0.10)	
LES040-0093	Bluhm Ditch	AA27022	Samp0058	2005-06-16	Backpack	5.1	5	5 (1.00)	--	
OSK-02-0021	Razor Fork	AB08536	Samp0057	2012-09-25	Backpack	5.1	5+	5 (1.00)	--	
WAW040-0152	Tributary of South Fork Wildcat Creek	AA21686	Samp1074	2004-08-03	Longline	7.0	5+	5(0.75)	6 (0.25)	
WEM060-0031	Little Otter Creek	AA48984	Samp0619	2007-07-31	Longline	8.2	4	4 (1.00)	--	
OBS130-0007	Bear Creek	AA27147	Samp0311	2005-06-21	Backpack	10.0	4	4 (0.90)	3 (0.10)	
WPA030-0017	Hall Creek	AA41568	Samp1196	2006-06-27	Scanoe	11.5	4+	4 (1.00)	--	
WEM020-0023	Graham Creek	AA46693	Samp0005	2007-08-01	Longline	12.4	4	4 (0.70)	3 (0.30)	

Table E2 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Notes
								Primary	Secondary	
WPA-04-0008	Polson Creek	AB08438	Samp0564	2012-07-17	Longline	12.6	5	5 (0.60)	4 (0.40)	
OML040-0012	Little Hogan Creek	AA62592	Samp0013	2010-08-30	Longline	12.7	4	4 (0.90)	3 (0.10)	
WPA-02-0003	Flat Creek	AB08428	Samp0337	2012-08-06	Longline	13.4	4	4 (0.83)	3 (0.17)	
WEM010-0016	Middle Fork Creek	AA46643	Samp1231	2007-07-03	Backpack	14.1	3-	3 (1.00)	--	
OSK-02-0009	Brushy Fork	AB08524	Samp1759	2012-09-25	Longline	15.3	3	3 (0.70)	4 (0.30)	
WWU100-0088	Sly Fork	AA54226	Samp0088	2008-08-12	Longline	16.3	4+	4 (0.60)	3 (0.40)	
WEL-04-0002	Little Salt Creek	AB12206	Samp0476	2013-06-11	Canoe	16.4	4	4 (0.80)	3 (0.20)	
WEL-01-0003	Rush Creek	AB12192	Samp0363	2013-07-09	Backpack	20.3	4-	4 (1.00)	--	
WEM-02-0001	Little Graham Creek	AB12201	Samp0496	2013-06-05	Backpack	22.2	5+	5 (0.55)	4 (0.45)	model 1/2 level better
WAE010-0029	Eel River	AA21751	Samp0392	2004-08-17	Longline	23.3	4/5 tie	4 (0.70)	5 (0.30)	model 1/2 level better
WEM020-0038	Little Graham Creek	AA46687	Samp0729	2007-08-01	Longline	24.0	5+	5 (1.00)	--	
LEA120-0011	Flatrock Creek	AA62616	Samp1113	2010-07-13	Longline	29.5	6	6 (0.60)	5 (0.40)	
WEM070-0027	Six Mile Creek	AA48828	Samp0782	2007-07-23	Longline	30.2	4	3 (0.50)	4 (0.50)	model 1/2 level better
WLV160-0041	Big Raccoon Creek	AA27427	Samp0094	2005-08-08	Longline	32.5	4	4 (1.00)	--	
WEM060-0024	Otter Creek	AA48792	Samp0418	2007-07-26	Longline	32.7	3	3 (0.90)	4 (0.10)	
WLV070-0013	Big Shawnee Creek	AA57892	Samp0774	2009-08-11	Scanoe	33.5	3+	3 (1.00)	--	
WPA030-0015	Hall Creek	AA41552	Samp0050	2006-06-28	Scanoe	36.5	4	4 (1.00)	--	

Table E2 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Notes
								Primary	Secondary	
WEM020-0034	Graham Creek	AA46681	Samp0549	2007-07-31	Longline	38.3	3-	3(0.62)	4 (0.38)	
WEM020-0032	Graham Creek	AA46683	Samp1266	2007-07-31	Longline	39.2	4	4 (0.60)	3 (0.40)	
WPA010-0042	Patoka River	AA41557	Samp0450	2006-06-05	Scanoe	39.6	4	4 (1.00)	--	
OML200-0004	Indian Creek	AA27164	Samp0236	2005-06-07	Backpack	43.4	4+	4 (0.82)	3 (0.18)	
WWU100-0087	Fall Creek	AA54225	Samp0048	2008-08-12	Longline	45.0	4	4 (0.94)	3 (0.06)	
OSK-02-0014	West Fork Indian Kentuck Creek	AB08529	Samp0083	2012-09-24	Canoe	46.0	3-	3 (0.60)	4 (0.40)	
WEL150-0010	Lost River	AA46649	Samp0416	2007-06-18	Backpack	53.9	4	4 (0.90)	5 (0.10)	
LEJ050-0068	Fish Creek	AA62639	Samp0115	2010-08-03	Scanoe	66.2	4+	4 (0.63)	3 (0.37)	
OSK070-0018	Fourteenmile Creek	AA62552	Samp0787	2010-07-07	Scanoe	66.2	3	3 (0.78)	4 (0.22)	
WEL110-0016	Indian Creek	AA46647	Samp1468	2007-06-06	Scanoe	69.3	3	3 (0.75)	4 (0.25)	
WEM060-0041	Otter Creek	AA48988	Samp1033	2007-07-30	Longline	70.8	3	3 (0.80)	4 (0.20)	
WAE010-0018	Solon Ditch	AA21697	Samp1470	2004-08-17	Longline	71.0	6	6 (1.00)	--	
WEL030-0010	Guthrie Creek	AA46656	Samp0276	2007-06-20	Scanoe	73.7	4-	4 (1.00)	--	
WAE010-0010	Eel River	AA21645	Samp0097	2004-09-15	Longline	84.6	4	4 (1.00)	--	
WEM-02-0002	Graham Creek	AB12185	Samp0184	2013-06-04	Backpack	86.1	4	4 (0.63)	3 (0.37)	
WAW030-0035	Middle Fork Wildcat Creek	AA17240	Samp0103	2003-08-05	Scanoe	111.2	4+	3 (0.90)	4 (0.10)	model 1 level better
OBS130-0002	South Fork Blue River	AA00419	Samp0098	2000-07-24	Backpack	126.0	4	4 (0.60)	5 (0.40)	

Table E2 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
OBS130-0002	South Fork Blue River	AB11757	Samp0831	2013-08-06	Backpack	126.0	4	4 (1.00)	--	
WEM-07-0004	Vernon Fork Muscatatuck River	AB12197	Samp0838	2013-07-30	Canoe	197.9	3	3 (1.00)	--	
OSK140-0041	Silver Creek	AA62560	Samp1028	2010-08-30	Scanoe	201.6	4-	4 (0.60)	3(0.4)	
WEM070-0032	Vernon Fork Muscatatuck River	AA48817	Samp1861	2007-07-24	Longline	207.5	3	3 (0.75)	4 (0.17)	
WWU-11-0005	Eagle Creek	AB03487	Samp1587	2011-07-19	Canoe	210.7	4	4 (1.00)	--	
WWU-13-0003	White Lick Creek	AB03479	Samp0539	2011-07-25	Canoe	214.9	3	3 (1.00)	--	
WEM070-0036	Vernon Fork Muscatatuck River	AA48818	Samp0743	2007-07-24	Longline	218.3	3+	3 (0.74)	2 (0.26)	
WPA-04-0005	Patoka River	AB08447	Samp1284	2012-07-18	Canoe	248.4	6	6 (1.00)	--	
WEU030-0047	Sand Creek	AA46670	Samp0002	2007-07-03	Scanoe	249.3	2-	2 (0.56)	3 (0.44)	model 1/2 level worse
WPA020-0052	Patoka River	AA41586	Samp0169	2006-10-11	Boat	249.9	6+	6 (0.80)	5 (0.20)	
WPA-04-0006	Patoka River	AB08430	Samp0808	2012-08-08	Canoe	260.4	3/4 tie	4 (1.00)	--	model 1/2 level worse
WED020-0029	Big Blue River	AA55373	Samp1371	2008-10-15	Scanoe	296.4	3	3 (1.00)	--	
WED020-0027	Big Blue River	AA55371	Samp1477	2008-10-15	Scanoe	296.7	4-	4 (1.00)	--	
OBS140-0008	Blue River	AA28831	Samp0677	2005-07-05	Scanoe	304.9	3	3 (0.70)	4 (0.20)	
OBS150-0027	Blue River	AA62580	Samp1120	2010-07-28	Scanoe	391.4	2	2 (0.75)	3 (0.25)	
OBS150-0022	Blue River	AA27170	Samp1640	2005-09-13	Scanoe	398.2	2-	2 (0.80)	3 (0.20)	

Table E2 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
OBS150-0021	Blue River	AB11761	Samp0749	2013-08-07	Canoe	459.7	3-	3 (0.75)	4 (0.25)	
WED-07-0001	Sugar Creek	AB12220	Samp0560	2013-06-17	Boat	470.0	3	3 (1.00)	--	
LEJ070-0026	Saint Joseph River	AA27955	Samp0091	2005-09-13	Boat	700.5	4	4 (1.00)	--	
GMW060-0016	Whitewater River	AA47274	Samp1635	2007-06-25	Boat	829.1	2	2 (1.00)	--	

Table E3. BCG level assignments and sample information for Eastern Corn Belt + Interior Plateau fish samples that were assessed during the confirmation exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 6 (0.75)/Secondary 5 (0.25) means that the model assigns the sample to BCG level 6, with a 0.75 probability of membership in both BCG level 6 & a 0.25 probability of membership in BCG level 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WAE030-0028	Schuman Ditch	AA21713	Samp0626	2004-09-24	Longline	4.4	6	6 (0.75)	5 (0.25)	
WAW040-0127	Mann Ditch	AA21610	Samp0436	2004-08-02	Longline	5.7	4	4 (0.76)	5 (0.24)	
WWU100-0110	Honey Creek	AA54247	Samp1478	2008-08-04	Longline	6.7	3-	3 (0.80)	4 (0.20)	
WWL-01-0003	Beanblossom Creek	AB03462	Samp0628	2011-07-26	Longline	13.9	3	3 (0.80)	4 (0.20)	
WLV080-0015	Opossum Run	AA57895	Samp0291	2009-07-06	Longline	15.7	3	3 (1.00)	--	
WAW040-0065	South Fork Wildcat Creek	AA21656	Samp0948	2004-08-09	Longline	81.6	3	3 (1.00)	--	
WEL-13-0024	Lost River	AB12199	Samp0823	2013-07-10	Canoe	117.2	4-	4 (0.80)	5 (0.20)	
WEL160-0027	Lost River	AA46646	Samp0537	2007-06-18	Scanoe	246.8	6	6 (1.00)	--	
WEF-06-0001	Flatrock River	AB13798	Samp1401	2013-07-31	Canoe	510.0	2	2 (0.90)	3 (0.10)	

Interior River Lowlands

Table E4. BCG level assignments and sample information for Interior River Lowland fish samples that were assessed during the calibration exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 4 (0.70)/Secondary 5 (0.30) means that the model assigns the sample to BCG level 4, with a 0.70 probability of membership in BCG level 4 and a 0.30 probability of membership in BCG level 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WBU200-0019	Tributary of Snapp Creek	AA57919	Samp1883	2009-06-02	Longline	1.0	4	4 (1.00)	--	
WPA040-0038	Altar Creek	AA41537	Samp0157	2006-06-19	Backpack	1.6	4-	4 (0.70)	5 (0.30)	
WLW110-0014	Clear Creek	AA57889	Samp1387	2009-06-03	Longline	2.6	4	4 (1.00)	--	
WPA-07-0009	Wheeler Creek	AB07942	Samp1867	2012-07-24	Longline	2.9	6	6 (1.00)	--	
WLW090-0006	Tributary of Black River	AA22705	Samp1339	2004-07-19	Backpack	4.2	4+	4 (1.00)	--	
WPA040-0044	Green Creek	AA41547	Samp1531	2006-06-20	Backpack	6.4	4/5 tie	5 (0.80)	4 (0.20)	model 1/2 level worse
WPA-07-0001	Rough Creek	AB09762	Samp0401	2012-08-21	Longline	8.6	5	5 (1.00)	--	
OLP110-0001	Honey Creek	AA62559	Samp0754	2010-07-07	Longline	9.6	4-	4 (1.00)	--	
WLW020-0003	Swan Pond Ditch	AA22698	Samp0448	2004-07-19	Backpack	22.6	5/6 tie	6 (1.00)	--	model 1/2 level worse
WPA070-0026	South Fork Patoka River	AB07939	Samp0487	2012-07-24	Canoe	23.2	4	4 (0.70)	5 (0.30)	
WWL090-0031	Veale Creek	AA41514	Samp0454	2006-06-19	Backpack	30.2	4-	4 (0.67)	5 (0.33)	
WPA070-0018	South Fork Patoka River	AA41553	Samp0877	2006-06-14	Scanoe	41.2	5+	5 (0.70)	4 (0.30)	
WWL040-0056	Plummer Creek	AA41515	Samp0189	2006-06-12	Scanoe	49.0	3	3 (0.86)	4 (0.14)	
WBU130-0005	Turman Creek	AA57884	Samp0035	2009-06-01	Scanoe	77.2	4	4 (1.00)	--	
WLV180-0041	Little Raccoon Creek	AA57905	Samp0036	2009-07-27	Scanoe	141.8	3-	3 (0.69)	4 (0.31)	

Table E4 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
OLP140-0095	Little Pigeon Creek	AA27139	Samp0884	2005-06-20	Scanoe	189.0	4	4 (1.00)	--	
WLW-07-0001	Big Creek	AB03991	Samp1554	2011-07-06	Canoe	253.1	5	5 (1.00)	--	
WPA040-0049	Patoka River	AA41588	Samp0676	2006-09-06	Boat	434.2	5+	5 (1.00)	--	
WPA040-0039	Patoka River	AA41584	Samp1446	2006-09-06	Boat	452.8	5+	5 (0.70)	4 (0.30)	
WPA040-0047	Patoka River	AA41587	Samp0429	2006-10-12	Boat	471.9	5/6 tie	5 (1.00)	--	model 1/2 level better
WPA-06-0007	Patoka River	AB08457	Samp1816	2012-08-21	Boat	593.5	4	4 (1.00)	--	
WWE-07-0004	Eel River	AB03461	Samp1721	2011-10-12	Boat	869.2	3-	3 (1.00)	--	

Table E5. BCG level assignments and sample information for Interior River Lowland fish samples that were assessed during the confirmation exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 4 (0.75)/Secondary 5 (0.25) means that the model assigns the sample to BCG level 4, with a 0.75 probability of membership in BCG level 4 and a 0.25 probability of membership in BCG level 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WLV120-0004	Jim Branch	AA22681	Samp0196	2004-06-28	Backpack	2.7	4	4 (0.75)	5 (0.25)	
WPA070-0029	Tributary of South Fork Patoka River	AB07940	Samp1247	2012-07-24	Longline	6.2	6	6 (0.56)	5 (0.44)	model 1/2 level better
WPA080-0048	Keg Creek	AA41560	Samp0747	2006-06-20	Backpack	6.3	5	5 (0.67)	6 (0.33)	
WWL080-0041	Killion Canal	AA41523	Samp1235	2006-06-19	Scanoe	12.2	4	4 (1.00)	--	
WLW050-0003	Brown Ditch	AA57899	Samp0908	2009-06-02	Longline	15.5	4-	5 (0.65)	4 (0.35)	model 1 level worse
WPA-05-0002	Flat Creek	AB08429	Samp0066	2012-07-10	Canoe	48.6	4	4 (1.00)	--	
WWL040-0056	Plummer Creek	AA42971	Samp0609	2006-07-05	Scanoe	49.0	3	3 (0.80)	4 (0.20)	
WPA-07-0002	South Fork Patoka River	AB08437	Samp1081	2012-07-24	Canoe	73.8	5+	5 (1.00)	--	
WLV140-0009	Little Vermilion River	AA57909	Samp1198	2009-06-30	Scanoe	203.2	3	3 (1.00)	--	
WPA080-0045	Patoka River	AA42193	Samp1628	2006-09-11	Boat	840.0	6	6 (1.00)	--	

Central Corn Belt Plains

Table E6. BCG level assignments and sample information for Central Corn Belt Plains fish samples that were assessed during the calibration exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 4 (0.50)/Secondary 5 (0.50) means that the model assigns the sample to a BCG level 4-5 tie, with a 0.50 probability of membership in both BCG levels 4 & 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
LMG050-0052	Tributary of Salt Creek	AA41833	Samp0664	2006-08-08	Longline	1.0	6	6 (1.00)	--	
UMK100-0012	Tributary of Wolf Creek	AA57930	Samp0935	2009-06-16	Longline	1.4	4	4 (1.00)	--	
WLV040-0053	Tributary of Big Pine Creek	AA57897	Samp0132	2009-06-09	Longline	2.5	4-	4 (0.83)	5 (0.17)	
LMG050-0023	Pepper Creek	AA41878	Samp1874	2006-08-02	Longline	3.0	5	5 (1.00)	--	
UMK-13-0012	Bull Run	AB03993	Samp0699	2011-06-29	Longline	3.3	4-	4 (1.00)	--	
UMK140-0016	Bull Run	AA26614	Samp0218	2005-08-01	Longline	3.5	6+	6 (0.93)	5 (0.07)	
UMI050-0052	Kent Ditch	AA28860	Samp0657	2005-08-30	Longline	3.5	4/5 tie	4 (0.50)	5 (0.50)	
LMG-05-0030	Tributary of Turkey Creek	AB11715	Samp0979	2013-06-25	Backpack	4.0	5/6 tie	5 (0.50)	6 (0.50)	
UMK130-0037	Stony Run	AA26656	Samp1553	2005-08-02	Longline	4.2	4	4 (0.67)	5 (0.33)	
UMI050-0041	Kent Ditch	AA28849	Samp0921	2005-08-30	Longline	4.5	4/5 tie	4 (0.50)	5 (0.50)	
UMI070-0019	Upper Sugar Creek	AA57962	Samp1767	2009-07-01	Longline	6.9	4+	3 (0.60)	4 (0.40)	model 1/2 level better
UMK130-0044	Bruce Ditch	AA26683	Samp0493	2005-08-03	Longline	9.2	4	4 (0.60)	3 (0.40)	
UMK130-0018	Stony Run	AA26651	Samp0528	2005-08-01	Longline	9.4	4	4 (1.00)	--	
UMK130-0067	Cedar Creek	AA26661	Samp1034	2005-08-03	Longline	9.9	6	6 (1.00)	--	
LMG-04-0011	Coffee Creek	AB07325	Samp0471	2012-06-04	Longline	12.3	4-	4 (1.00)	--	
UMK100-0008	Wolf Creek	AA22642	Samp1720	2004-06-07	Backpack	14.2	4+	4 (0.60)	3 (0.40)	

Table E6 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WLV040-0011	Little Pine Creek	AA22715	Samp1503	2004-06-30	Backpack	15.2	3-	3 (0.52)	4 (0.48)	model 1/2 level worse
WLV040-0011	Little Pine Creek	AA23335	Samp1766	2004-07-20	Backpack	15.2	3/4 tie	3 (0.53)	4 (0.47)	
UMI050-0039	Montgomery Ditch	AA28846	Samp1429	2005-08-30	Longline	16.9	4	4 (0.75)	3 (0.25)	
UMK130-0069	Cedar Creek	AA26663	Samp0694	2005-08-03	Longline	21.9	6	6 (1.00)	--	
WLV040-0019	Big Pine Creek	AA26707	Samp1269	2005-08-10	Longline	24.0	5+	5 (1.00)	--	
UMK130-0074	Tributary of Cedar Creek	AA26670	Samp0917	2005-08-03	Longline	27.2	6	6 (0.67)	5 (0.33)	
LMG050-0086	Salt Creek	AA41883	Samp0022	2006-08-02	Longline	33.8	5-	5 (1.00)	--	
UMI070-0014	Sugar Creek	AA22649	Samp0510	2004-06-09	Backpack	36.4	3-	4 (0.52)	3 (0.48)	model 1/2 level worse
UMK130-0055	Singleton Ditch	AA26644	Samp1840	2005-08-02	Longline	53.0	4-	4 (1.00)	--	
UMK140-0010	West Creek	AA22670	Samp0281	2004-07-07	Scanoe	54.4	3/4 tie	4 (0.71)	3 (0.29)	model 1/2 level worse
LMG030-0022	Deep River	AA27039	Samp0857	2005-07-05	Scanoe	60.4	4-	4 (0.70)	5 (0.30)	
LMG050-0008	Salt Creek	AA41842	Samp0632	2006-08-08	Longline	63.7	5	5 (1.00)	--	
LMG050-0053	Salt Creek	AA41835	Samp1854	2006-08-08	Longline	68.7	5	5 (0.90)	4 (0.10)	
WLV040-0041	Big Pine Creek	AA26735	Samp1328	2005-08-08	Longline	117.8	4	4 (1.00)	--	
UMK130-0001	Singleton Ditch	AA26635	Samp0788	2005-08-03	Longline	123.0	4	3 (0.50)	4 (0.50)	model 1/2 level better
UMI020-0027	Iroquois River	AA57967	Samp1021	2009-07-08	Boat	203.3	4	3 (0.67)	4 (0.33)	model 1 level better
UMI020-0019	Iroquios River	AA22664	Samp1457	2004-07-07	Scanoe	212.7	3	3 (1.00)	--	
WBU020-0023	Brouilletts Creek	AA22683	Samp1256	2004-06-29	Scanoe	267.3	3	3 (1.00)	--	
UMK060-0046	Yellow River	AA57939	Samp1253	2009-07-20	Boat	373.5	4+	4 (0.60)	3 (0.40)	
UMK060-0047	Yellow River	AA57946	Samp0442	2009-07-13	Boat	435.5	3	3 (1.00)	--	
UMK060-0048	Yellow River	AA57957	Samp1236	2009-06-16	Scanoe	439.0	3	3 (0.77)	4 (0.23)	
UMK040-0010	Kankakee River	AA57931	Samp0821	2009-07-14	Boat	642.8	4	4 (1.00)	--	

Table E7. BCG level assignments and sample information for Central Corn Belt Plains fish samples that were assessed during the confirmation exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 6 (1.00)/Secondary (--) means that the model assigns the sample to BCG level 6, with a full (1.00) probability of membership in BCG level 6. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WLV040-0038	Brumm Ditch	AA26729	Samp0467	2005-08-09	Longline	2.5	4	4 (0.83)	5 (0.17)	
UMK140-0031	Tributary of West Creek	AA26628	Samp0072	2005-08-02	Longline	2.7	4/5 tie	5 (0.75)	4 (0.17)	model 1/2 level worse
WLV200-0007	Norton Creek	AA57886	Samp0166	2009-06-01	Longline	3.0	3/4 tie	3 (0.50)	4 (0.50)	
WLV040-0016	Miller Ditch	AA26703	Samp1135	2005-08-10	Longline	5.7	4-	5 (1.00)	--	model 1 level worse
UMK-13-0008	West Creek	AB03983	Samp0370	2011-06-28	Longline	13.1	4-	4 (1.00)	--	
LMG050-0080	Salt Creek	AA41873	Samp0250	2006-08-07	Longline	41.8	5	5 (1.00)	--	
LMG050-0077	Salt Creek	AA41868	Samp0129	2006-08-07	Longline	46.4	5	5 (0.67)	6 (0.33)	
UMK130-0079	Singleton Ditch	AA57947	Samp1201	2009-06-15	Scanoe	86.9	4	4 (1.00)	--	
UMK130-0036	Singleton Ditch	AA22648	Samp0793	2004-07-07	Scanoe	135.7	5+	5 (0.85)	4 (0.15)	
UMI020-0023	Iroquois River	AA57932	Samp1086	2009-07-06	Scanoe	163.1	3	3 (1.00)	--	
UMK030-0033	Kankakee River	AA22643	Samp0768	2004-09-14	Boat	519.4	4	4 (0.90)	5 (0.10)	

Southern Michigan/Northern Indiana Drift Plains

Table E8. BCG level assignments and sample information for Southern Michigan/Northern Indiana Drift Plains fish samples that were assessed during the calibration exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 4 (0.80)/Secondary 5 (0.20) means that the model assigns the sample to BCG level 4, with a 0.80 probability of membership in BCG level 4 and a 0.20 probability of membership in BCG level 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WTI090-0004	Travers Ditch	AA17254	Samp0796	2003-07-22	Backpack	1.2	4	4 (1.00)	--	
LMG-04-0018	Sand Creek	AB07319	Samp0580	2012-06-04	Backpack	2.1	4-	4 (0.80)	5 (0.20)	
LMG050-0108	Parker Ditch	AA41917	Samp0070	2006-07-31	Longline	2.4	5	5 (0.80)	4 (0.20)	
LMG-04-0002	Peterson Ditch	AB07332	Samp1024	2012-05-18	Longline	3.2	5	5 (0.73)	4 (0.27)	
WTI100-0003	Swingle Ditch	AA51785	Samp0769	2008-06-23	Backpack	4.0	4	4 (1.00)	--	
LMG050-0107	Parker Ditch	AA41916	Samp0277	2006-07-31	Longline	4.3	6	6 (0.70)	5 (0.30)	
LMJ200-0052	Kieffer Ditch	AA27067	Samp1747	2005-06-22	Backpack	4.6	4-	4 (1.00)	--	
LMG-04-0033	Tributary of Reynolds Creek	AB07296	Samp1077	2012-06-06	Longline	5.1	4-	4 (0.83)	5 (0.17)	
UMK010-0025	Collins Ditch	AA22651	Samp1111	2004-07-06	Backpack	5.2	5	5 (1.00)	--	
LMG-04-0015	Coffee Creek	AB07322	Samp0127	2012-06-05	Longline	6.7	5	5 (0.90)	4 (0.10)	
LMG050-0112	Salt Creek	AA41903	Samp1001	2006-08-01	Longline	7.0	5	5 (1.00)	--	
LMG-04-0039	East Branch Little Calumet River	AB07309	Samp1752	2012-06-05	Backpack	8.2	5	5 (1.00)	--	
LMJ200-0051	Omar-Neff Ditch	AA27036	Samp1895	2005-06-27	Backpack	10.1	6+	6 (0.90)	5 (0.10)	
LMJ210-0024	Rock Run Creek	AA27040	Samp0427	2005-06-29	Backpack	11.1	4	4 (1.00)	--	
LMJ190-0026	Stony Creek	AA28837	Samp1100	2005-07-06	Backpack	18.1	4-	4 (1.00)	--	
WTI020-0061	Deeds Creek	AA51792	Samp0931	2008-06-18	Scanoe	20.7	4	4 (1.00)	--	
WTI060-0035	House Ditch	AA51803	Samp1359	2008-06-30	Scanoe	23.9	3	4 (0.70)	3 (0.30)	model 1 level worse
LMJ220-0014	Cobus Creek	AA62617	Samp1735	2010-07-13	Longline	25.5	4/5 tie	4 (1.00)	--	model 1/2 level better
WTI010-0006	Grassy Creek	AB11769	Samp1484	2013-07-08	Backpack	34.7	4-	4 (0.60)	5 (0.40)	

Table E8 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
LMG-04-0020	East Branch Little Calumet River	AB07317	Samp0244	2012-06-06	Canoe	41.1	5	5 (1.00)	--	
LMJ190-0031	Elkhart River	AA62622	Samp0661	2010-08-11	Scanoe	44.2	3-	3 (0.81)	4 (0.19)	
LMJ180-0049	South Branch Elkhart River	AA62651	Samp0741	2010-07-21	Longline	52.6	4	4 (1.00)	--	
LMJ140-0028	Little Elkhart River	AA27031	Samp0550	2005-07-07	Scanoe	60.4	4	4 (1.00)	--	
LMG-04-0004	East Branch Little Calumet River	AB07330	Samp1255	2012-06-06	Canoe	66.0	4/5 tie	4 (1.00)	--	model 1/2 level better
LMG060-0008	East Branch Little Calumet River	AB07335	Samp0622	2012-06-05	Canoe	71.0	5	5 (0.79)	4 (0.21)	
LMG-04-0043	East Branch Little Calumet River	AB07290	Samp0589	2012-06-12	Boat	77.3	4-	4 (1.00)	--	
LMJ140-0118	Little Elkhart River	AA62635	Samp0466	2010-07-14	Scanoe	117.3	4-	4 (1.00)	--	
LMJ120-0040	Pigeon River	AA27038	Samp0744	2005-09-26	Scanoe	222.8	3	3 (0.90)	4 (0.10)	
UMK050-0067	Yellow River	AA57951	Samp0267	2009-07-20	Scanoe	257.2	4+	4 (0.66)	3 (0.34)	
WTI030-0026	Tippecanoe River	AA51811	Samp0346	2008-06-30	Boat	259.4	4	4 (0.60)	3 (0.40)	
UMK050-0062	Yellow River	AA22676	Samp0313	2004-07-12	Scanoe	261.5	3/4 tie	4 (0.54)	3 (0.46)	
LMJ120-0041	Pigeon River	AA27047	Samp0284	2005-06-15	Scanoe	286.0	3-	3 (0.58)	4 (0.42)	model 1/2 level worse
LMJ190-0025	Elkhart River	AA27033	Samp1579	2005-06-28	Scanoe	289.5	4	4 (1.00)	--	
WTI040-0042	Tippecanoe River	AA51773	Samp0994	2008-07-07	Boat	515.5	3	3 (0.8)	2 (0.20)	
WTI060-0037	Tippecanoe River	AA51779	Samp1689	2008-07-08	Boat	915.4	3+	3 (0.74)	2 (0.26)	

Table E9. BCG level assignments and sample information for Southern Michigan/Northern Indiana Drift Plains fish samples that were assessed during the confirmation exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 5 (1.00)/Secondary (--) means that the model assigns the sample to BCG level 5, with a full (1.00) probability of membership in BCG level 5. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
LMG-04-0022	Tributary of East Branch Little Calumet	AB07304	Samp0746	2012-06-04	Backpack	3.1	5+	5 (1.00)	--	
WAE040-0019	Wheeler Creek	AA51799	Samp0224	2008-06-18	Backpack	4.0	5+	5 (1.00)	--	
WTI050-0033	J M Robbins Ditch	AA54116	Samp0735	2008-07-07	Longline	5.5	4	4 (0.80)	5 (0.20)	
LMJ240-0046	Bowman Creek	AA62626	Samp0294	2010-08-03	Longline	6.1	5-	5 (0.67)	6 (0.33)	
LMJ-21-0009	Wisler Ditch	AB03988	Samp1773	2011-06-14	Longline	9.2	4	4 (1.00)	--	
LMJ230-0009	Grimes Ditch	AA27042	Samp0457	2005-06-16	Scanoe	9.6	5+	4 (0.83)	5 (0.17)	model 1 level better
LMG060-0041	East Arm Little Calumet River	AA62640	Samp0873	2010-07-12	Longline	29.9	5	5 (1.00)	--	
LMG-04-0006	East Branch Little Calumet River	AB07328	Samp0141	2012-06-05	Canoe	48.3	4/5 tie	4 (0.79)	5 (0.21)	model 1/2 level better
LMJ110-0128	Pigeon Creek	AA62631	Samp0049	2010-07-20	Scanoe	127.1	3/4 tie	3 (0.50)	4 (0.50)	
LMJ120-0048	Pigeon River	AA62638	Samp1515	2010-07-13	Scanoe	287.8	3	3 (0.80)	4 (0.20)	

Large Rivers

Table E10. BCG level assignments and sample information for large river fish samples that were assessed during the calibration exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 5 (0.75)/Secondary 4 (0.25) means that the model assigns the sample to BCG level 5, with a 0.75 probability of membership in BCG level 5 and a 0.25 probability of membership in BCG level 4. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
Kankakee River_85.3	Kankakee	--	Samp2009	2004-08-03	Boat	1000.0	4	4 (1.00)	--	
Kankakee River_98.3	Kankakee	--	Samp2011	2004-08-03	Boat	1000.0	4-	4 (0.50)	5 (0.50)	model 1/2 level worse
WED100-0011	Driftwood River	AA49909	Samp0616	2007-08-22	Boat	1105.4	2	2 (1.00)	--	
UMK080-0014	Kankakee	AA22654	Samp0517	2004-09-14	Boat	1233.6	4-	4 (0.70)	5 (0.30)	
UMK080-0018	Kankakee	AA57937	Samp1085	2009-08-05	Boat	1314.9	3-	3 (0.76)	4 (0.24)	
UMK080-0015	Kankakee	AA22660	Samp0481	2004-09-14	Boat	1378.6	4+	4 (1.00)	--	
WTI150-0018	Tippecanoe	AA51815	Samp1453	2008-06-23	Boat	1865.0	3+	2 (0.71)	3 (0.29)	model 1 level better
WTI150-0018	Tippecanoe	AA54118	Samp1775	2008-09-11	Scanoe	1865.0	2	2 (1.00)	--	
LEM010-0051	Maumee	AA62650	Samp0726	2010-08-09	Boat	1948.2	5	5 (0.67)	4 (0.33)	
LMJ150-0023	Saint Joseph	AA62620	Samp1223	2010-08-17	Boat	2495.8	4-	4 (0.80)	3 (0.10)	
WEU060-0009	East Fork White	AA49913	Samp0225	2007-09-26	Boat	2567.8	3	3 (1.00)	--	
WWL050-0036	West Fork White	AA41576	Samp0809	2006-10-02	Boat	4754.0	4-	4 (0.90)	5 (0.10)	
WEL140-0005	East Fork White River	AA49911	Samp0464	2007-09-24	Boat	5075.1	4	4 (1.00)	--	

Table E10 continued…

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WWL090-0030	West Fork White	AA41575	Samp0197	2006-10-03	Boat	5278.1	5	5 (0.67)	4 (0.33)	
Wabash River_257.2	Wabash	--	Samp2004	2004-09-13	Boat	8300.0	4+	4 (1.00)	--	
WLV090-0008	Wabash	AA24599	Samp0006	2004-10-12	Boat	8309.1	4	4 (0.90)	5 (0.10)	
WWL-10-0005	White	AB03460	Samp0182	2011-09-14	Boat	11033.0	4	4 (0.67)	3 (0.33)	
WWL100-0023	White	AA41579	Samp0390	2006-10-03	Boat	11046.6	5	5 (1.00)	--	
WLV200-0008	Wabash	AA57920	Samp0130	2009-09-14	Boat	11699.5	4	4 (1.00)	--	
Wabash River_219.5	Wabash	--	Samp2000	2004-09-15	Boat	12100.0	3	3 (1.00)	--	
WBU030-0070	Wabash	AA57915	Samp1038	2009-09-14	Boat	12104.2	3-	3 (0.67)	4 (0.33)	
WBU180-0004	Wabash	AA24602	Samp0432	2004-10-14	Boat	13575.0	4-	4 (0.80)	5 (0.20)	
Wabash River_133.5	Wabash	--	Samp2005	2004-09-23	Boat	13600.0	4-	4 (0.60)	5 (0.40)	
WBU200-0015	Wabash	AA24605	Samp1089	2004-10-13	Boat	13768.7	5	5 (0.90)	4 (0.10)	
WLW010-0003	Wabash	AA57907	Samp1865	2009-09-22	Boat	16218.7	4-	4 (0.80)	5 (0.20)	

Table E11. BCG level assignments and sample information for large river fish samples that were assessed during the confirmation exercise. Samples are sorted by drainage area. The BCG model entries include probabilities of membership (in parentheses); for example, Primary 4 (0.70)/Secondary 3 (0.30) means that the model assigns the sample to BCG level 4, with a 0.70 probability of membership in BCG level 4 and a 0.30 probability of membership in BCG level 3. Model assignments are considered to be a tie if the difference between the primary and secondary memberships is less than 0.2.

StationID	Waterbody Name	IDEM SampID	Tt SampID	Collection Date	Collection Method	DrArea (mi2)	Panelist consensus	BCG Model		Difference
								Primary	Secondary	
WWE090-0043	Eel	AA41577	Samp0060	2006-10-10	Boat	1028.0	5+	5 (1.00)	--	
GMW080-0040	Whitewater	AA47265	Samp0765	2007-06-11	Boat	1282.9	2-	2 (0.57)	3 (0.43)	model ½ level worse
UMK110-0009	Kankakee	AA22656	Samp1225	2004-09-15	Boat	1754.6	4	4 (1.00)	--	
LEM010-0039	Maumee	AA27069	Samp1351	2005-10-12	Scanoe	1884.1	4	4 (0.95)	5 (0.05)	
WEU-02-0001	East Fork White	AB12189	Samp1620	2013-09-17	Boat	2052.8	2-	2 (0.66)	3 (0.34)	
WEL010-0010	East Fork White	AA49912	Samp1060	2007-09-25	Boat	3748.8	3-	3 (0.70)	4 (0.30)	
WEL-14-0001	East Fork White	AB12202	Samp0456	2013-10-17	Boat	5084.9	4+	4 (1.00)	--	
WLV010-0028	Wabash	AA57893	Samp0529	2009-09-16	Boat	7300.7	2-	2 (0.71)	3 (0.29)	
WBU070-0004	Wabash	AA57890	Samp0731	2009-09-23	Boat	12627.5	4-	4 (0.90)	5 (0.10)	

Appendix F

Box Plots of All Metrics

Box plots were generated to examine the distributions of metric values across BCG levels for each region/collection method group.

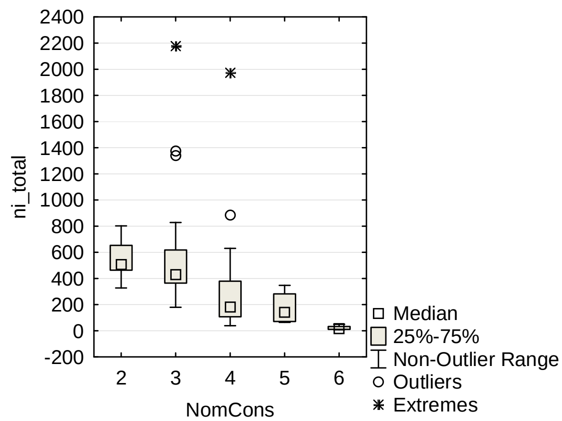
Table F1. Descriptions of the metric codes that are on the y-axes of the box plots.

Metric code	Description
ni_total	number of total individuals
nt_total	number of total taxa
nt_total_native	number of total native taxa
bio_total	total biomass
nt_att1	number of Attribute I taxa
nt_att10	number of Attribute X taxa
nt_att2	number of Attribute II taxa
nt_att12	number of Attribute I + II taxa
nt_att3	number of Attribute III taxa
nt_att123	number of Attribute I + II + III taxa
nt_att12310	number of Attribute I + II + III + X taxa
nt_att4	number of Attribute IV taxa
nt_att1234	number of Attribute I + II + III + IV taxa
nt_att123410	number of Attribute I + II + III + IV + X taxa
nt_att5	number of Attribute V taxa
nt_att6	number of Attribute VI
nt_att56	number of Attribute V + VI taxa
pt_att1	percent Attribute I taxa
pt_att10	percent Attribute X taxa
pt_att2	percent Attribute II taxa
pt_att12	percent Attribute I + II taxa
pt_att3	percent Attribute III taxa
pt_att123	percent Attribute I + II + III taxa
pt_att12310	percent Attribute I + II + III + X taxa
pt_att4	percent Attribute IV taxa
pt_att1234	percent Attribute I + II + III + IV taxa
pt_att123410	percent Attribute I + II + III + IV + X taxa
pt_att5	percent Attribute V taxa
pt_att6	percent Attribute VI taxa
pt_att56	percent Attribute V + VI taxa
pi_att1	percent Attribute I individuals
pi_att10	percent Attribute X individuals
pi_att2	percent Attribute II individuals
pi_att12	percent Attribute I + II individuals
pi_att3	percent Attribute III individuals
pi_att123	percent Attribute I + II + III individuals

Table F1. continued…

Metric code	Description
pi_att12310	percent Attribute I + II + III + X individuals
pi_att4	percent Attribute IV individuals
pi_att1234	percent Attribute I + II + III + IV individuals
pi_att123410	percent Attribute I + II + III + IV + X individuals
pi_att5	percent Attribute V individuals
pi_att6	percent Attribute VI individuals
pi_att56	percent Attribute V + VI individuals
pi_dom01_att4	percent individuals - domininant Attribute IV taxon
pi_dom01_att5	percent individuals - domininant Attribute V taxon
pi_dom01_att6	percent individuals - domininant Attribute VI taxon
pi_dom01_att56	percent individuals - domininant Attribute V + VI taxon
nt_catfish	number of catfish taxa
nt_darter	number of darter taxa
nt_DartSculpMad	number of darter + sculpin + madtom taxa
nt_minnow	number of minnow taxa
nt_suckers	number of sucker taxa
nt_sunfish	number of sunfish taxa
nt_NatInvert	number of native invertivore taxa (based on Illinois's designations)
pbio_att1	percent biomass Attribute I taxa
pbio_att10	percent biomass Attribute X taxa
pbio_att2	percent biomass Attribute II taxa
pbio_att12	percent biomass Attribute I + II taxa
pbio_att3	percent biomass Attribute III taxa
pbio_att123	percent biomass Attribute I + II + III taxa
pbio_att12310	percent biomass Attribute I + II + III + X taxa
pbio_att4	percent biomass Attribute IV taxa
pbio_att1234	percent biomass Attribute I + II + III + IV taxa
pbio_att123410	percent biomass Attribute I + II + III + IV + X taxa
pbio_att5	percent biomass Attribute V taxa
pbio_att6	percent biomass Attribute VI taxa
pbio_att56	percent biomass Attribute V + VI taxa
pctDELT	percent individuals with DELT anomalies
nt_att6i	number of Attribute VIi
pt_att6i	percent Attribute VIi taxa
pi_att6i	percent Attribute VIi individuals
pbio_att6i	percent biomass Attribute VIi taxa

Eastern Corn Belt Plains + Interior Plateau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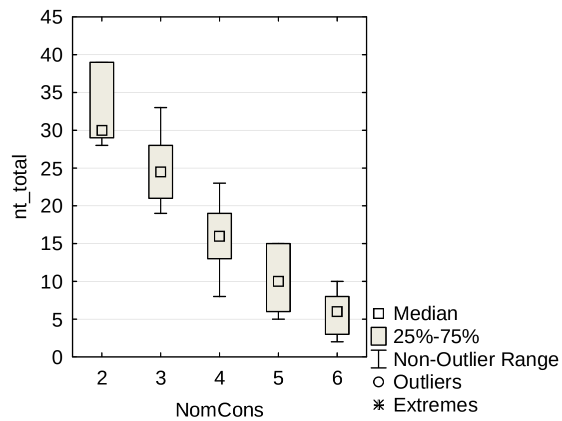
Non-Outlier Range
Outliers
Extremes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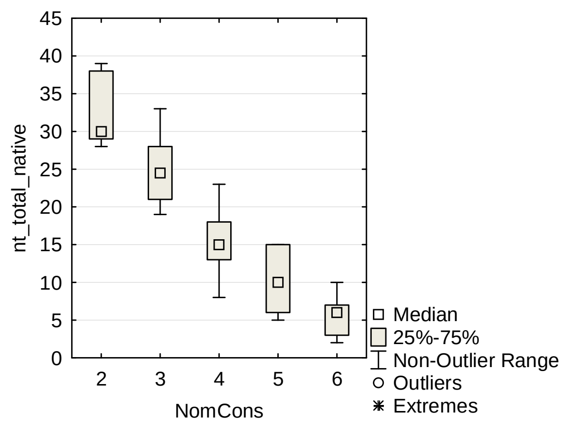
Non-Outlier Range
Outliers
Extremes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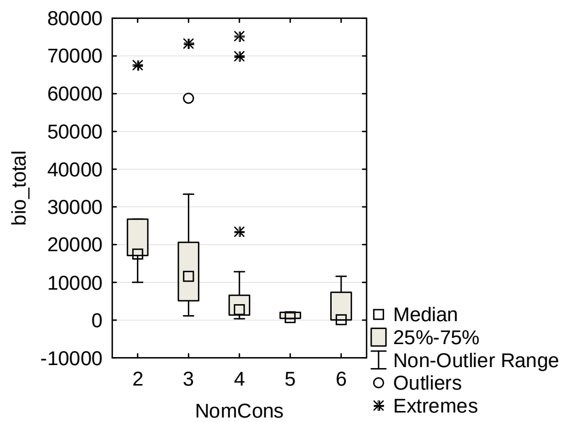
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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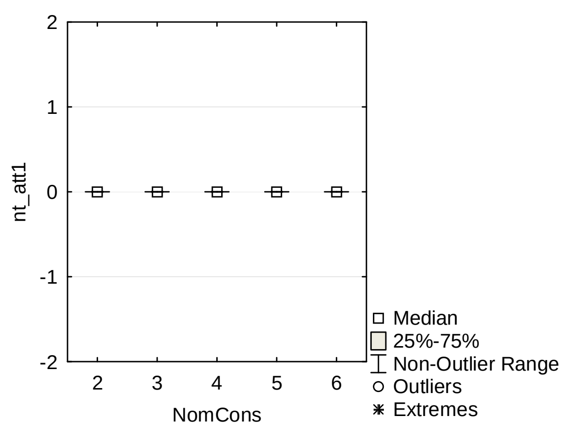
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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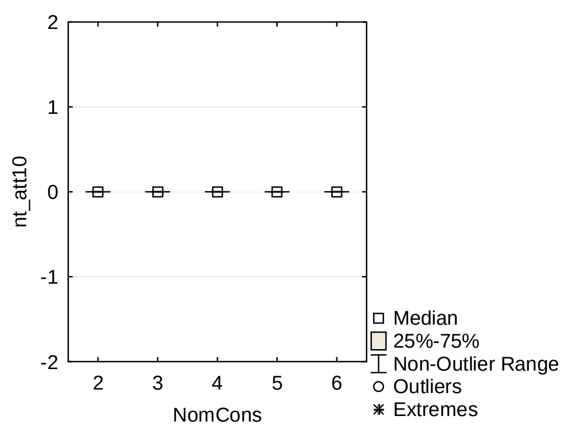
25%-75%
Non-Outlier Range
Outliers
Extremes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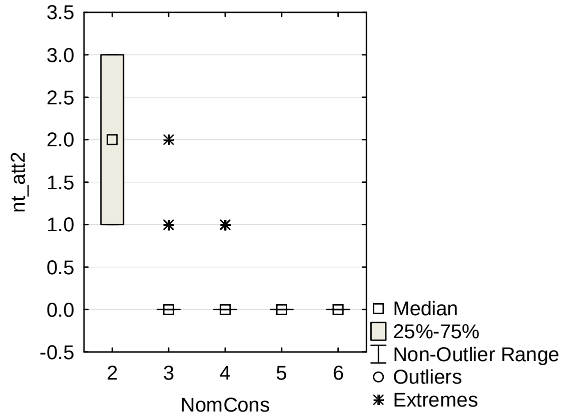
25%-75%
Non-Outlier Range
Outliers
Extremes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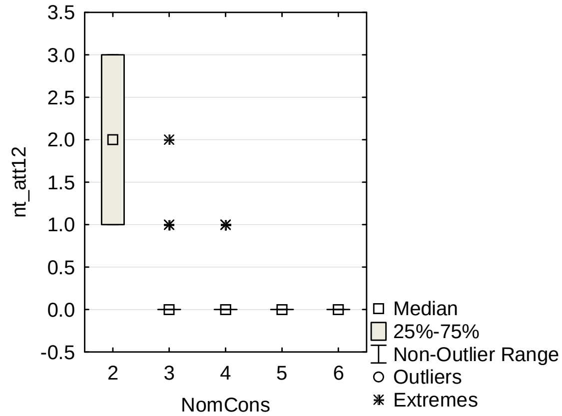
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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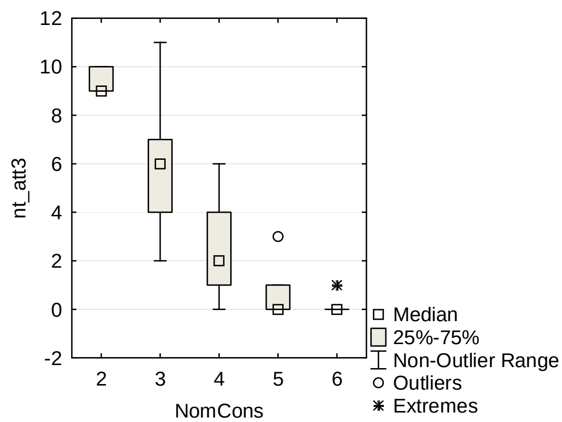
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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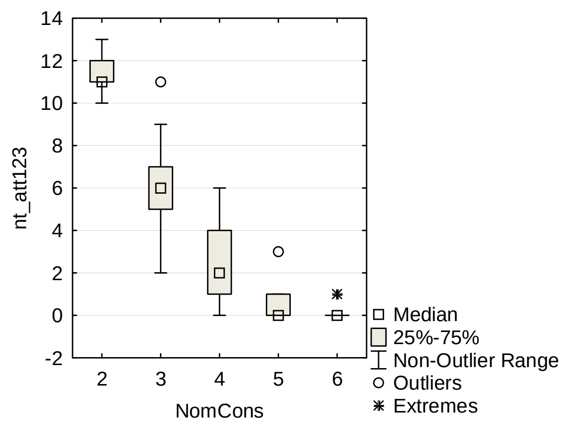
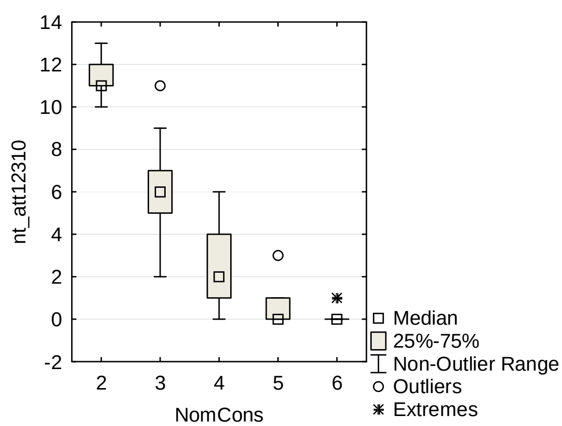
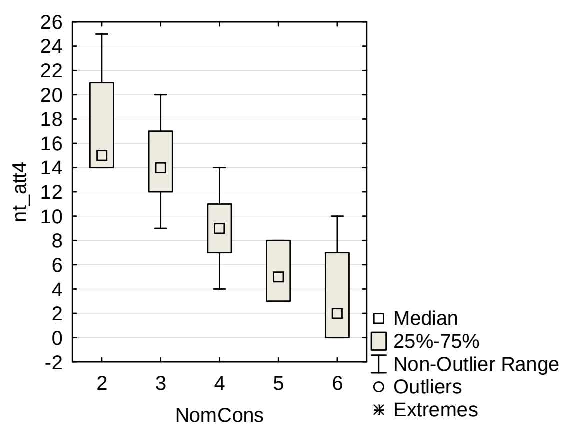
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att123
NomCons
2 3 4 5 6
-2 0 2 4 6 8 10 12 14
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att12310
NomCons
2 3 4 5 6
-2 0 2 4 6 8 10 12 14
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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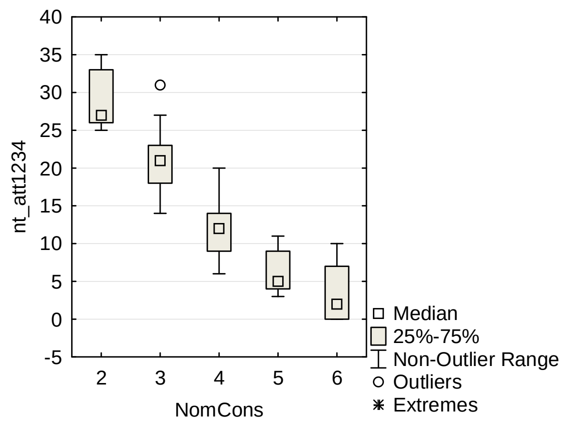
-2 0 2 4 6 8 10 12 14 16 18 20 22 24 26
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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20
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-5
2
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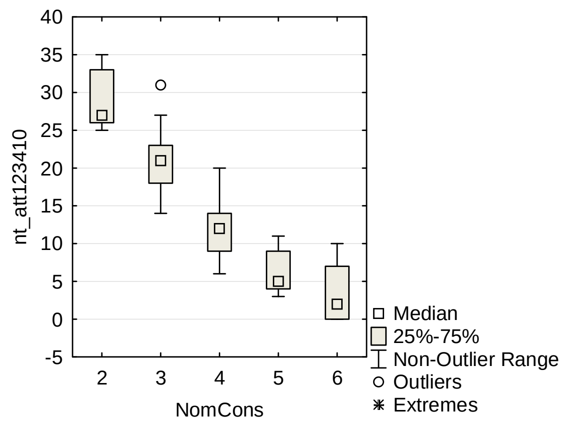
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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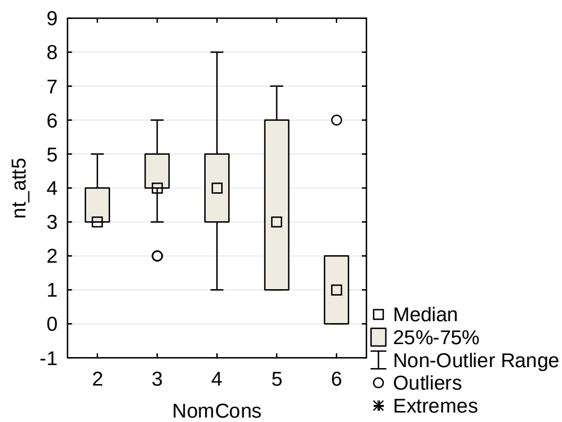
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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6
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-1
2
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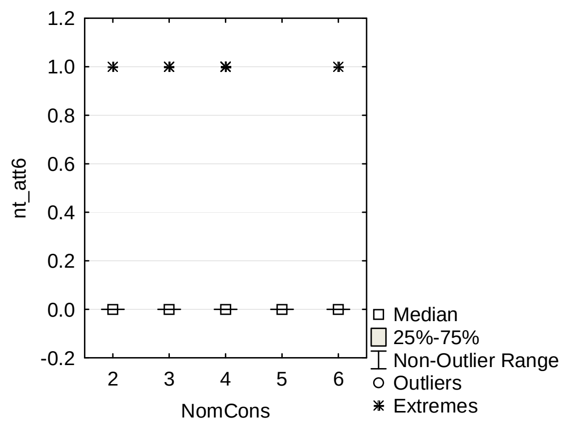
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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1.0
0.8
0.6
0.4
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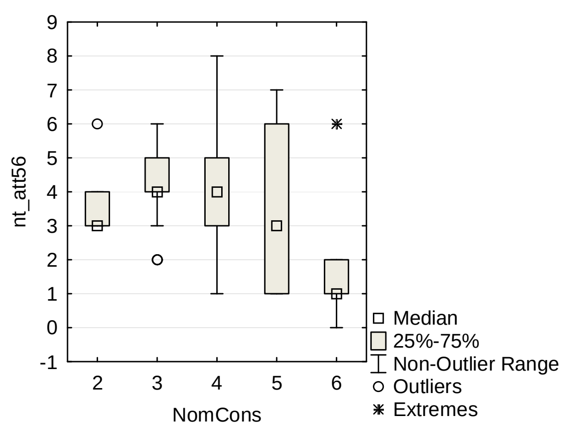
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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9
8
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6
5
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-1
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3
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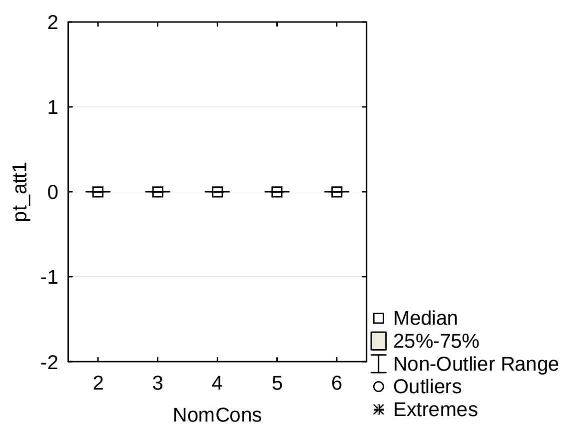
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att1
2
1
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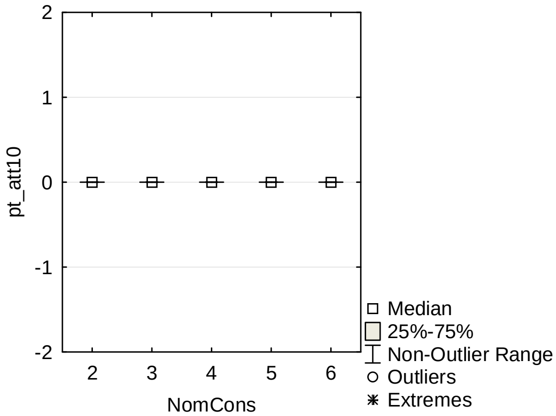
-1
-2
2
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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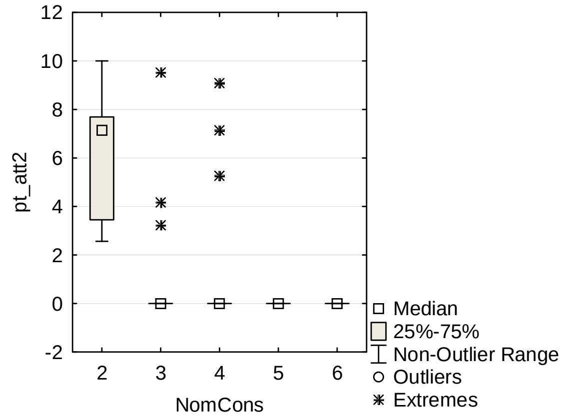
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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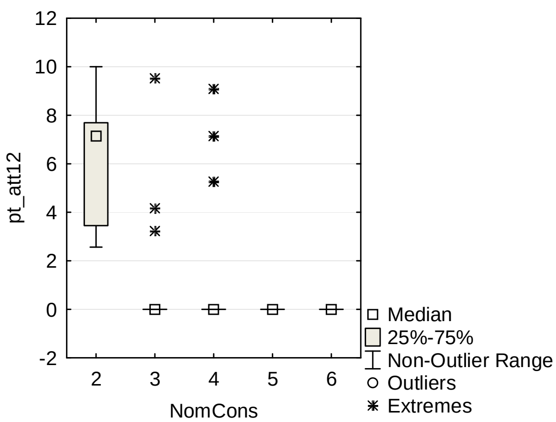
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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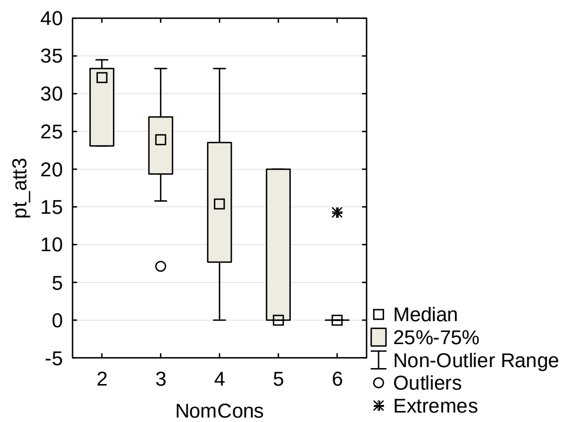
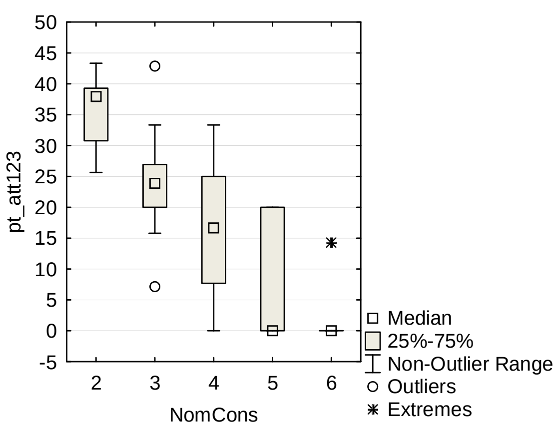
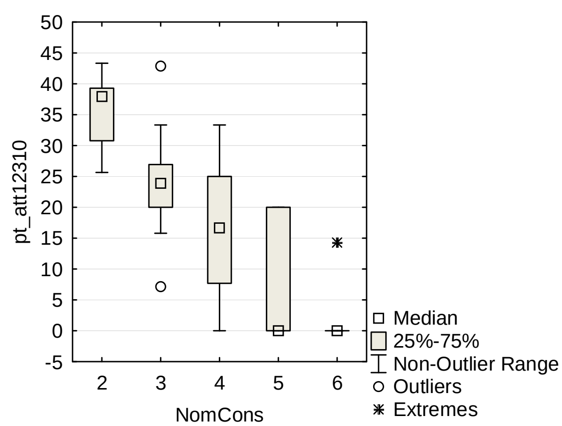
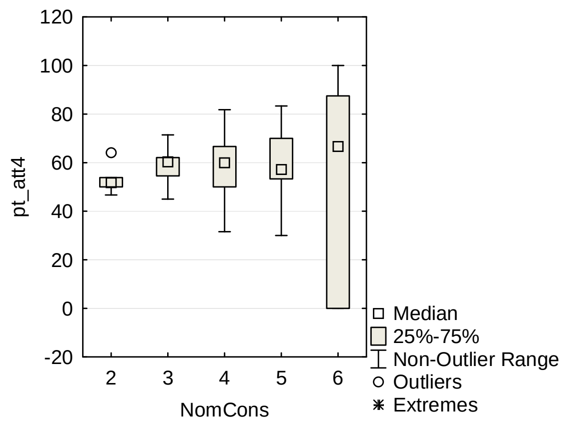
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att3
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att123
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att12310
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att4
120
100
80
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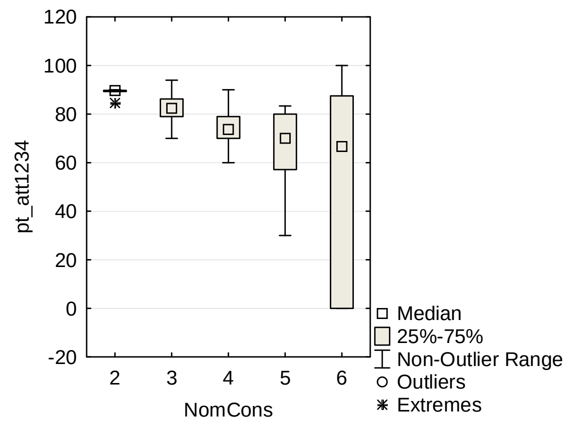
-20
2
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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120
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2
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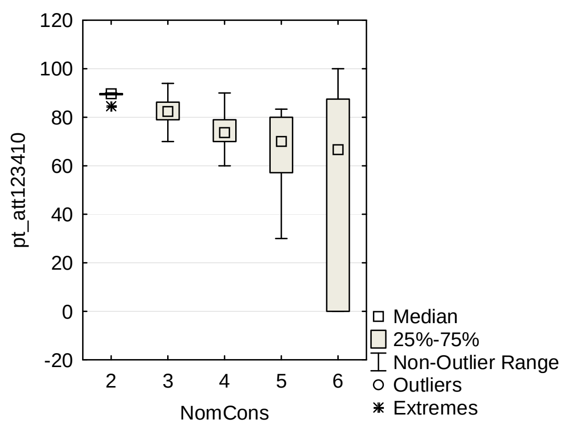
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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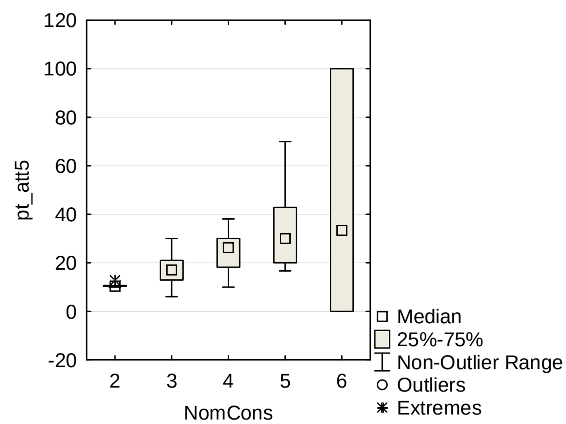
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att5
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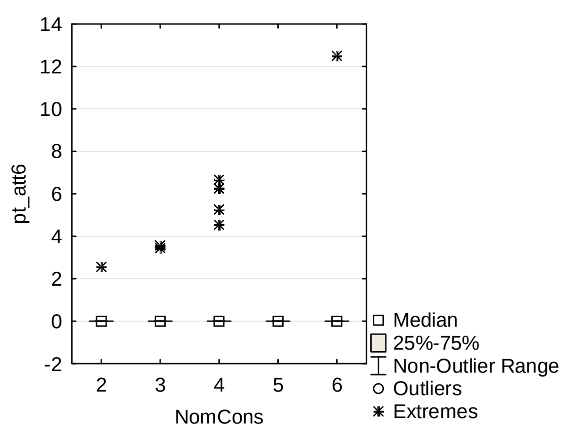
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att6
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12
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8
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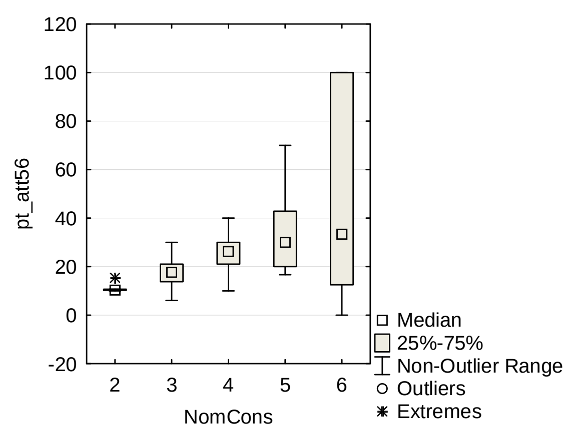
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att56
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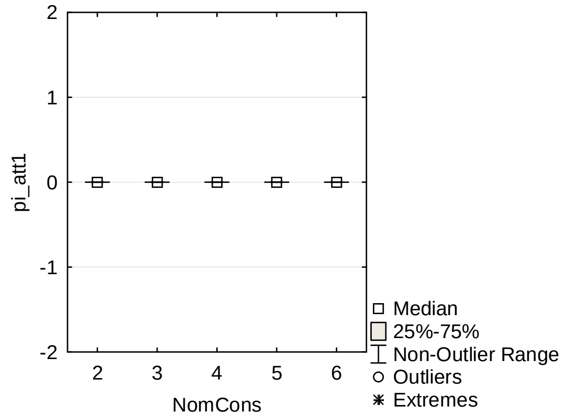
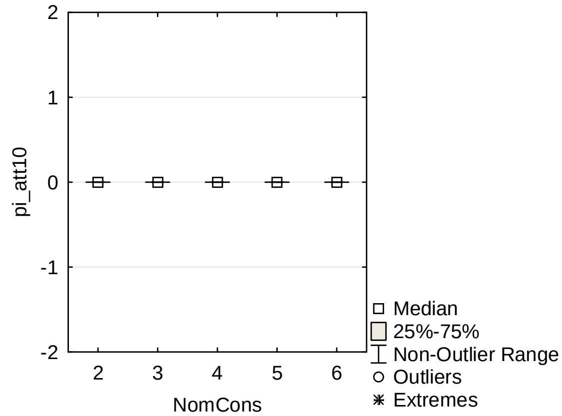
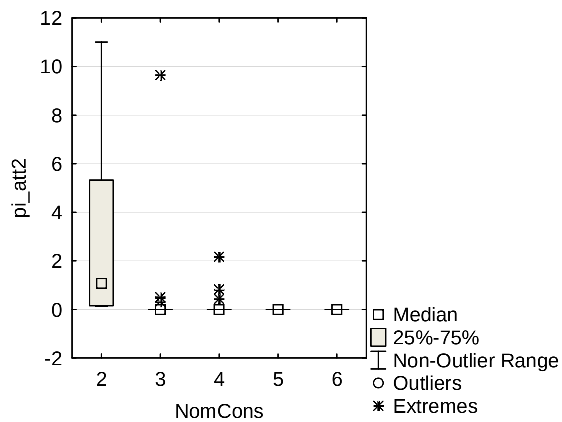
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att1
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att10
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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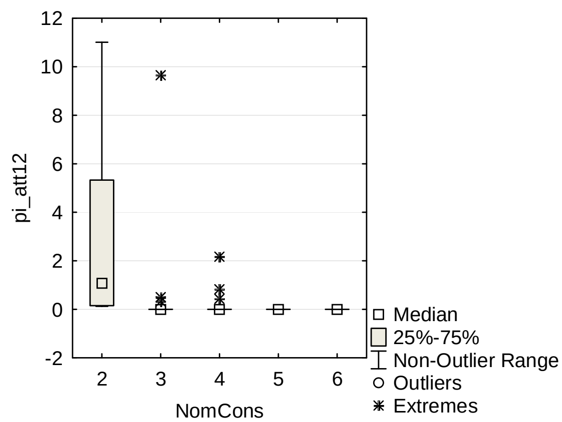
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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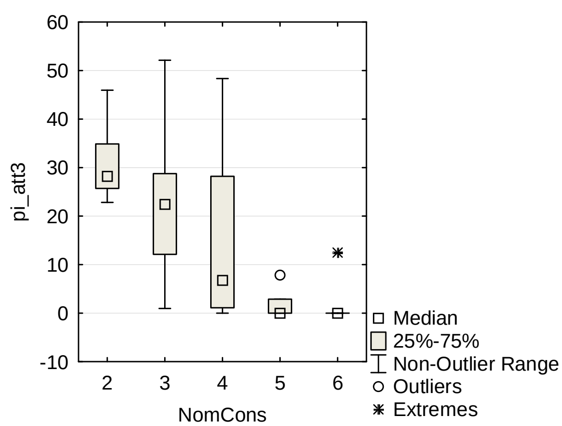
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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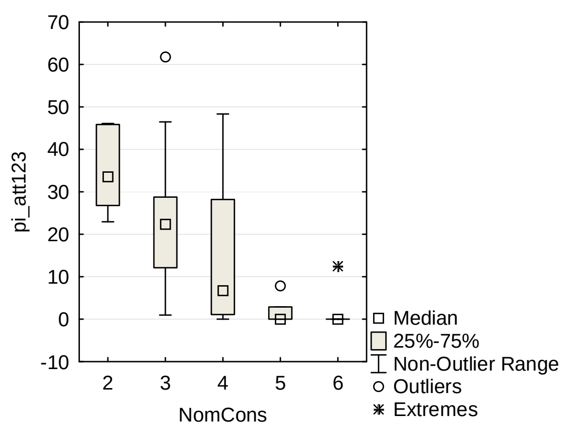
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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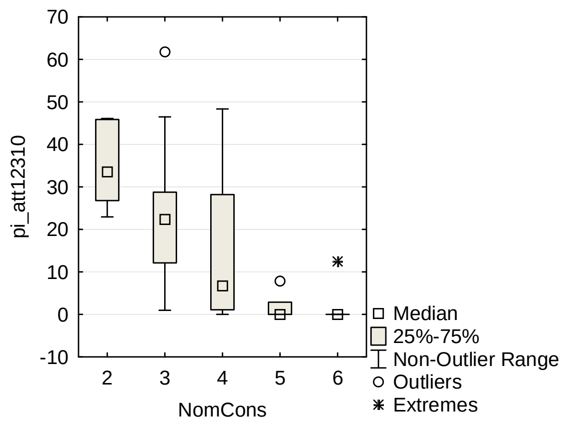
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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-10
2
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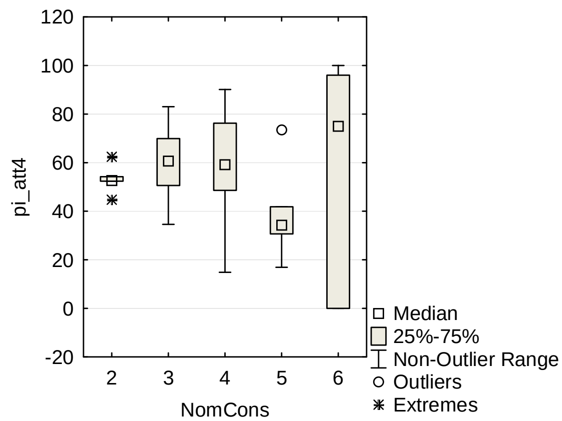
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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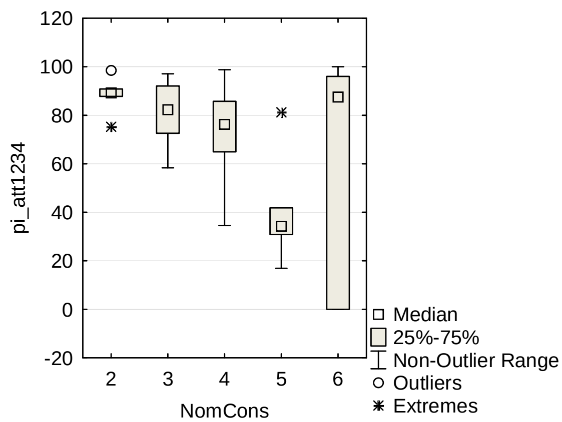
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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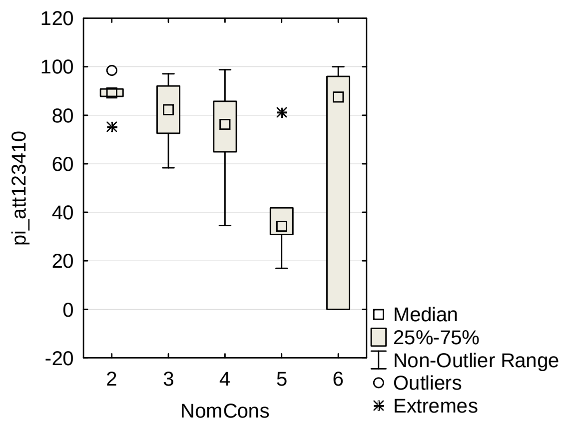
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
Median
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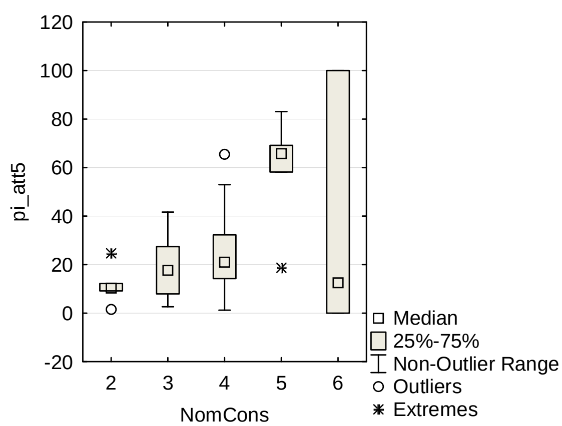
Non-Outlier Range
Outliers
Extremes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NomCons
Median
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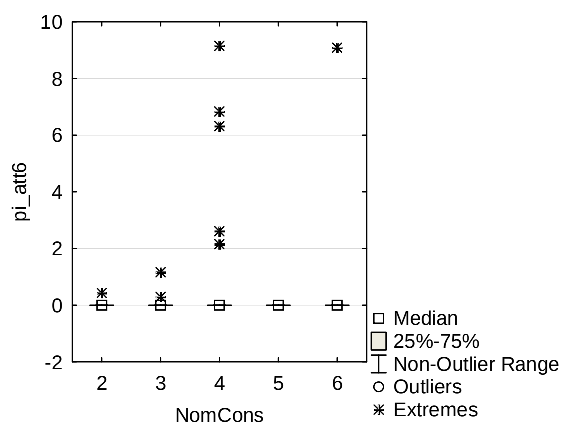
Non-Outlier Range
Outliers
Extremes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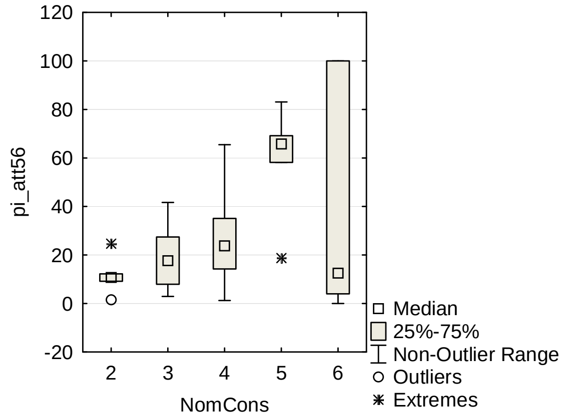
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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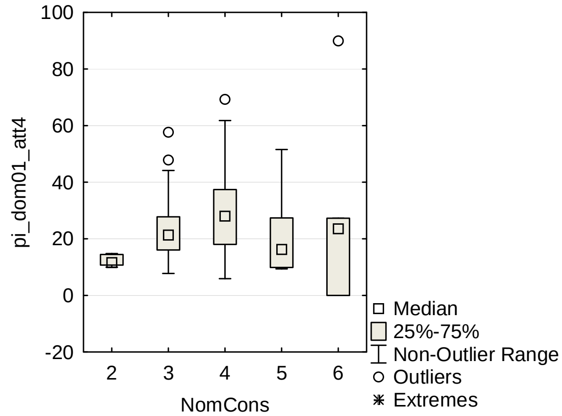
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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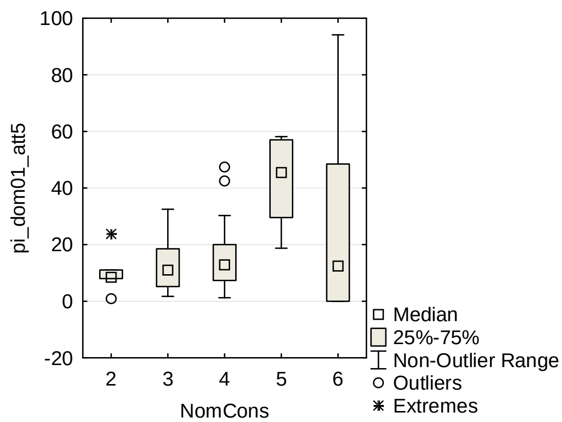
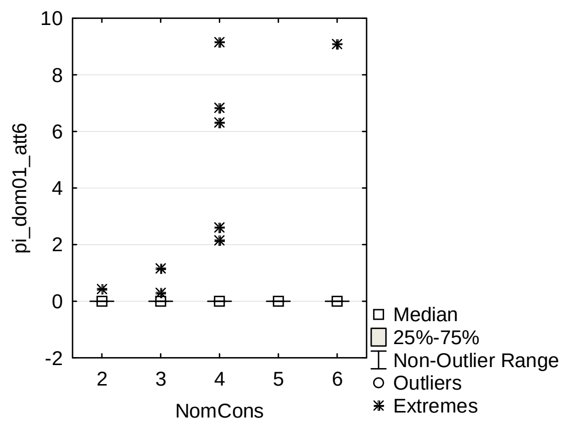
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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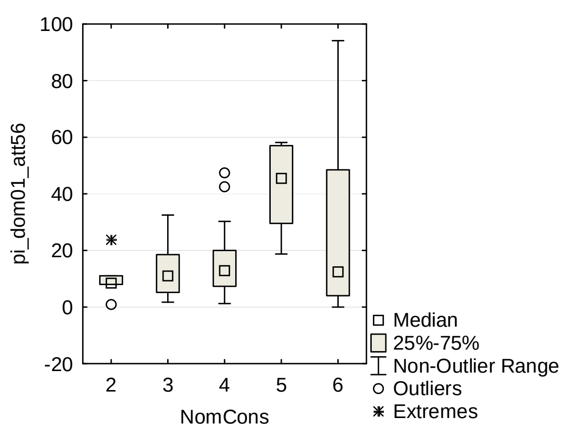
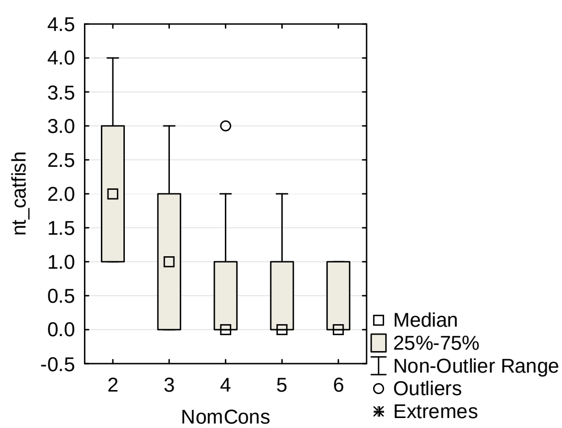
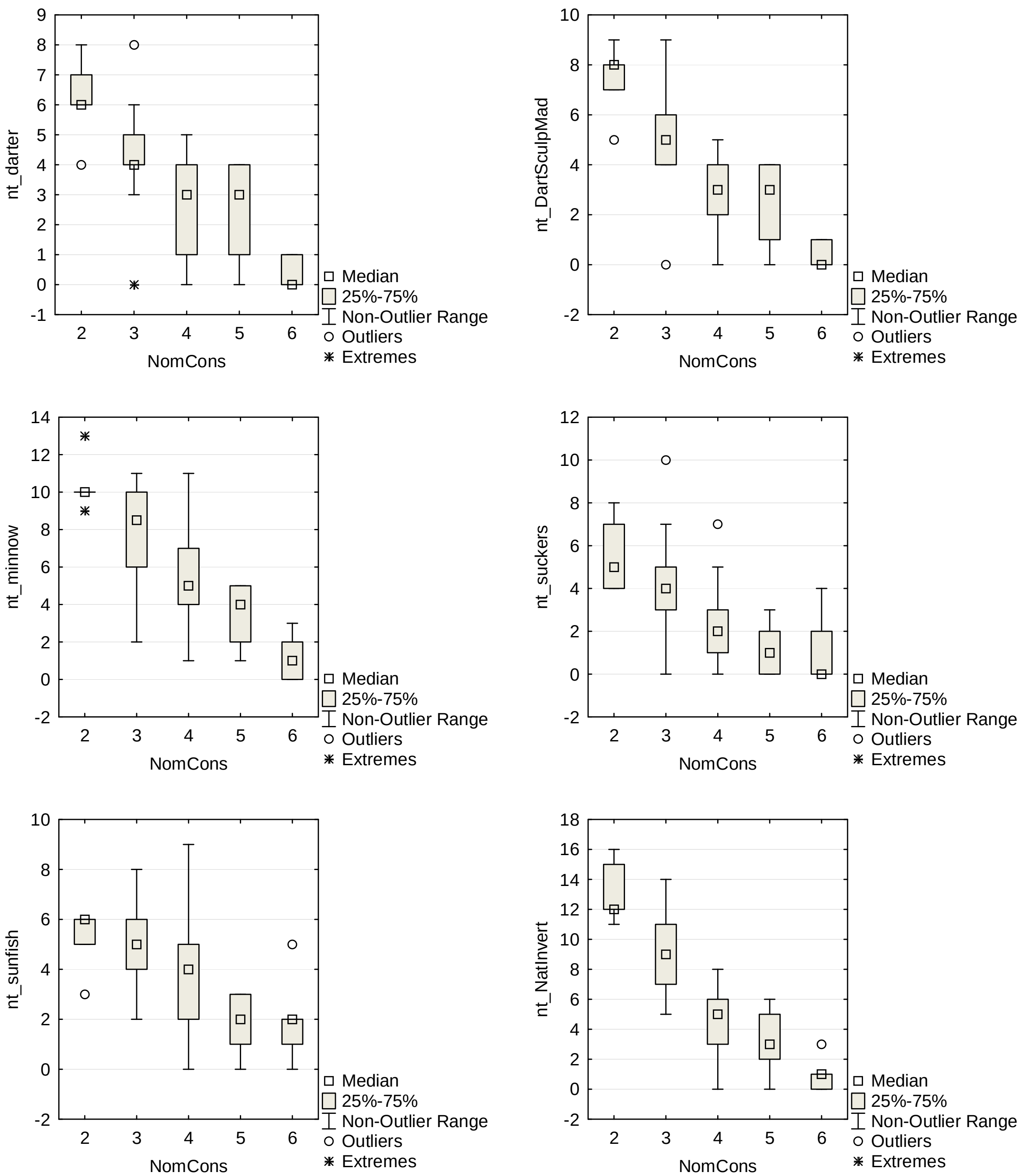
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att56
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_catfish
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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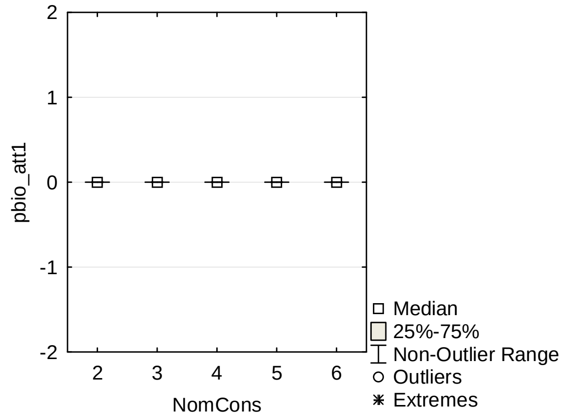
nt_DartSculpMad
nt_minnow
nt_suckers
nt_sunfish
nt_NatInvert
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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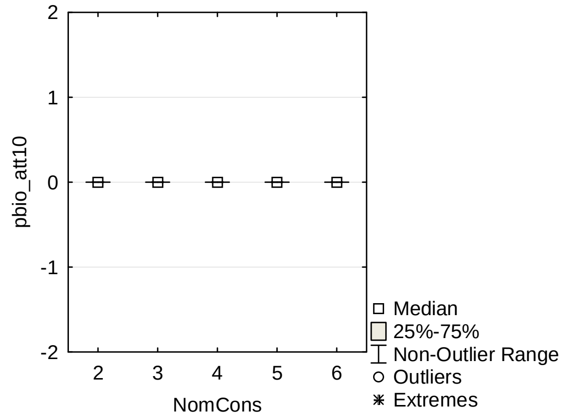
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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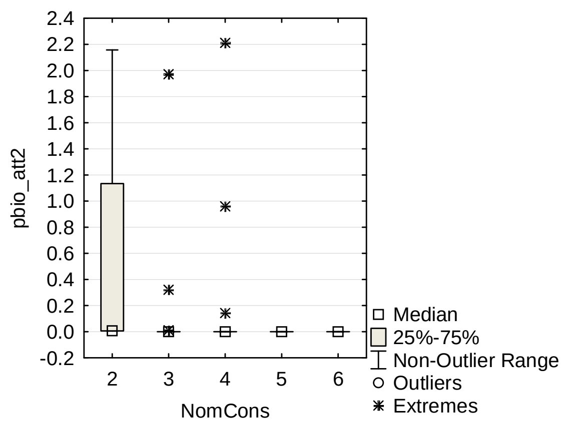
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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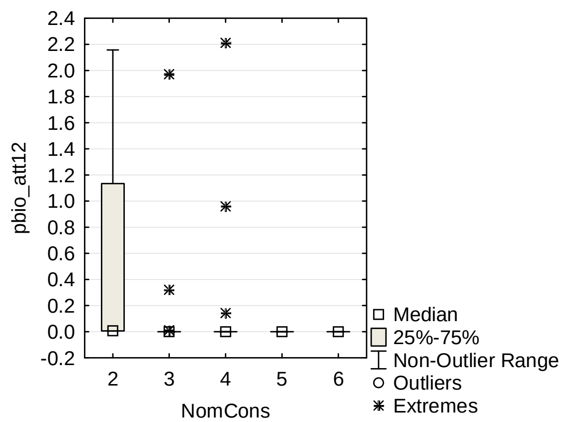
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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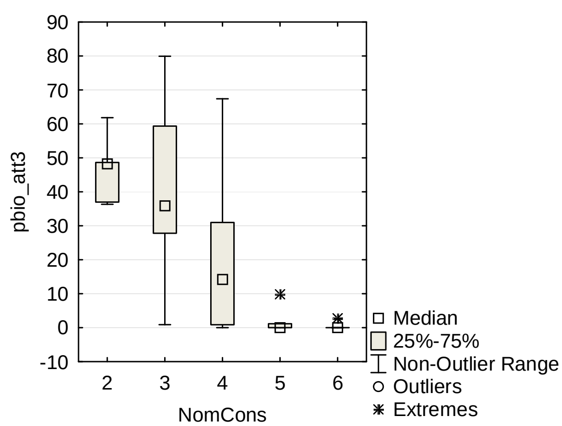
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att3
NomCons
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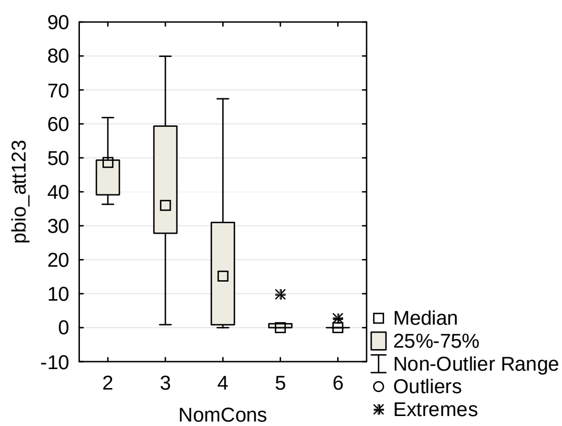
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att123
NomCons
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4
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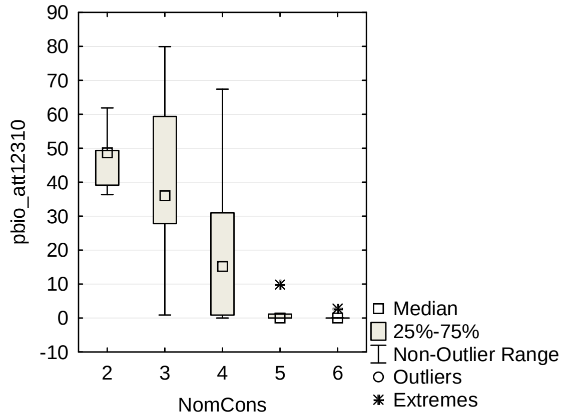
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att12310
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4
5
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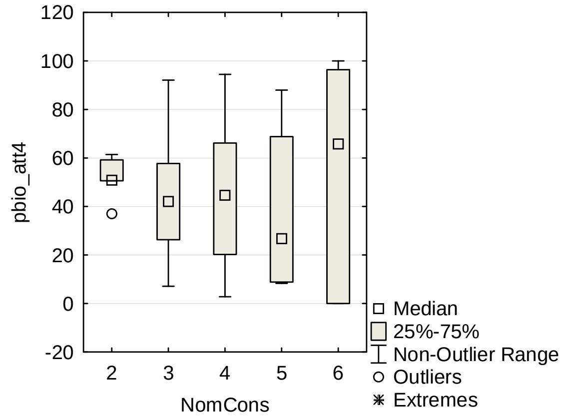
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
Median
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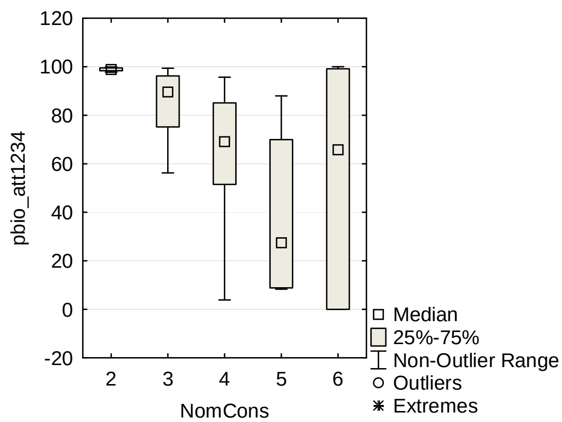
Non-Outlier Range
Outliers
Extremes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Median
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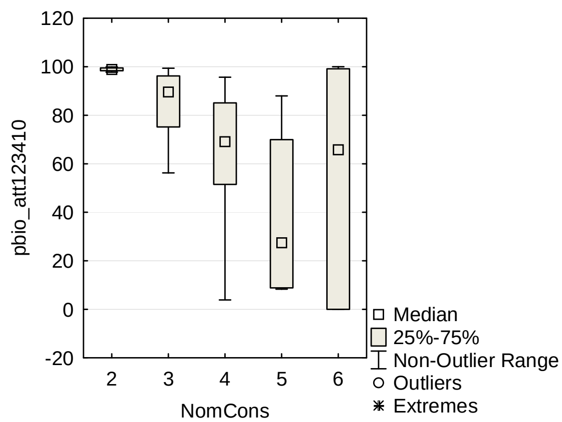
Non-Outlier Range
Outliers
Extremes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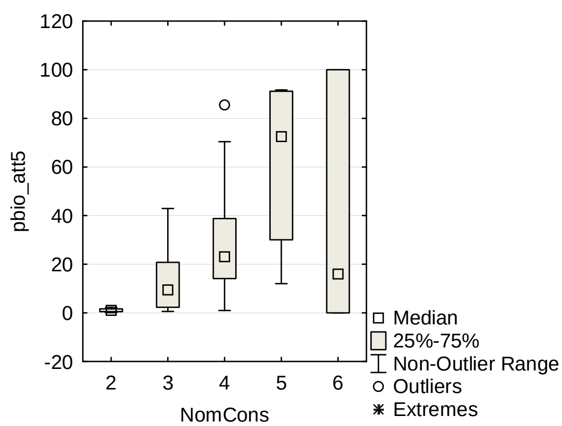
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att5
120
100
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-20
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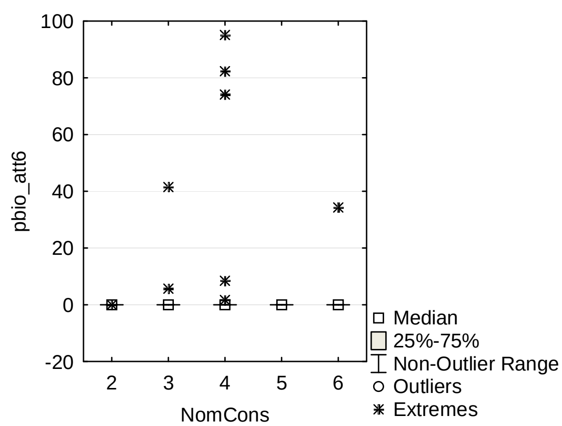
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att6
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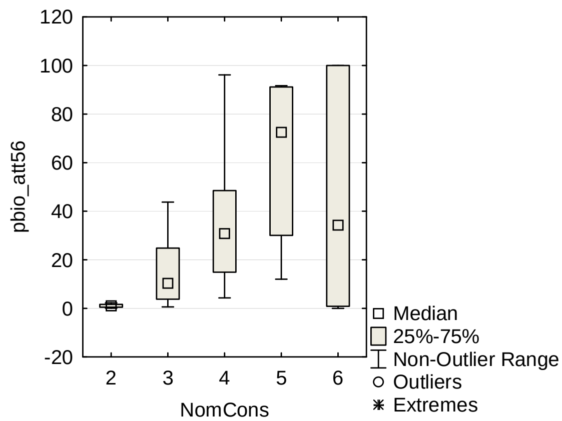
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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Median
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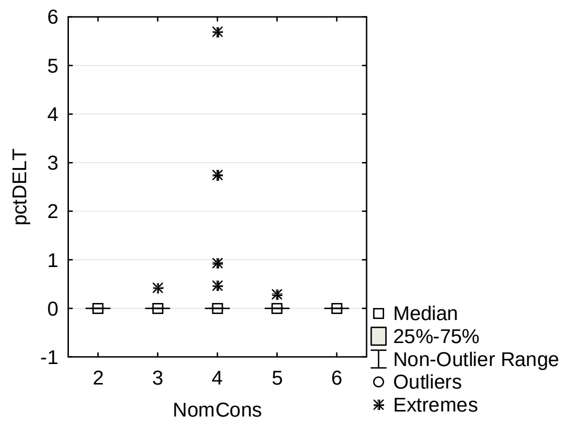
Non-Outlier Range
Outliers
Extremes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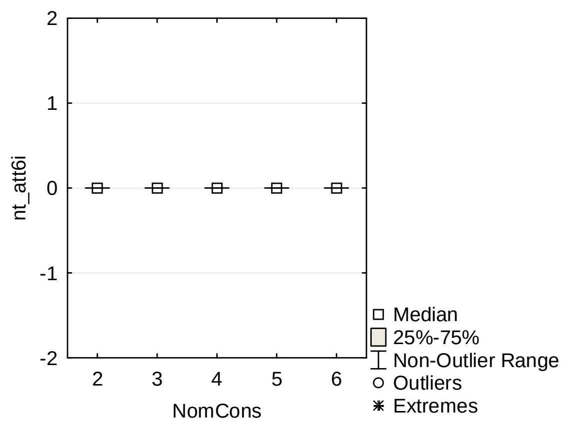
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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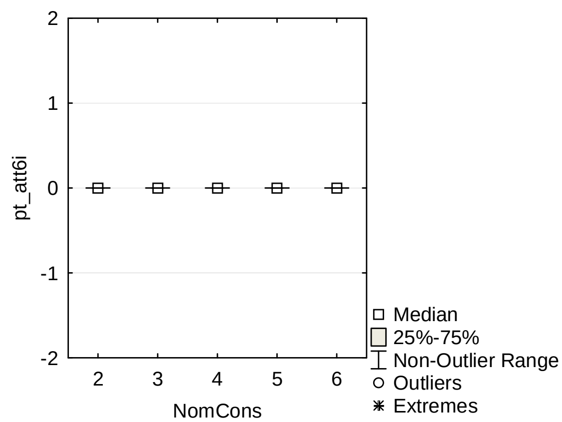
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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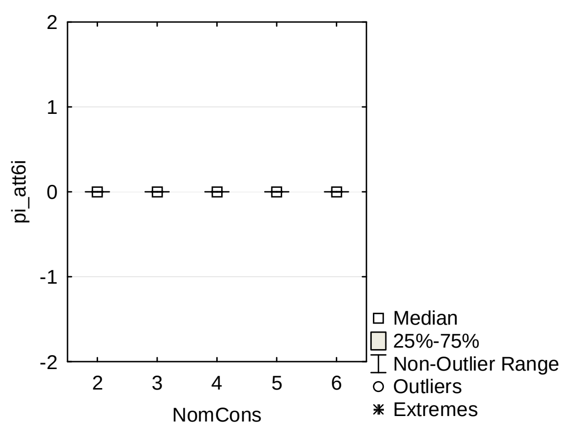
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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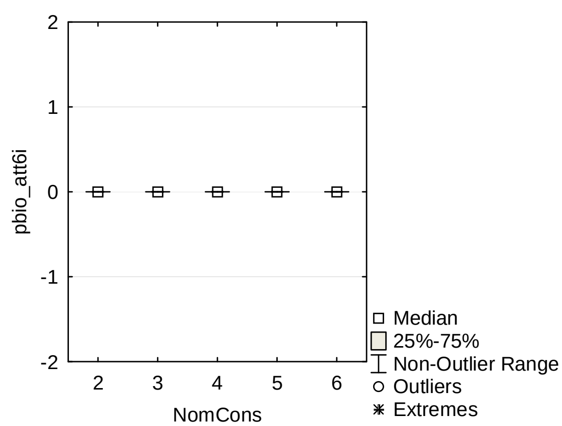
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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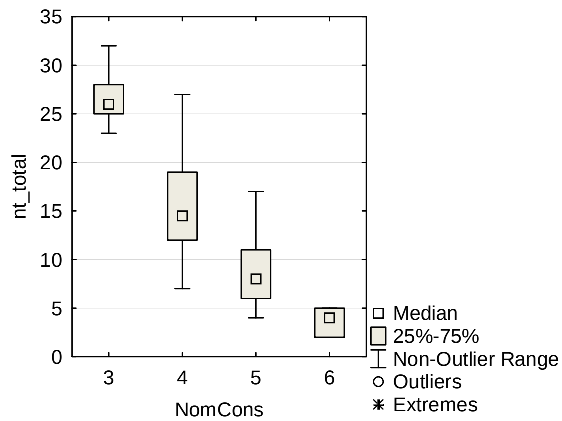
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Interior River Lowlands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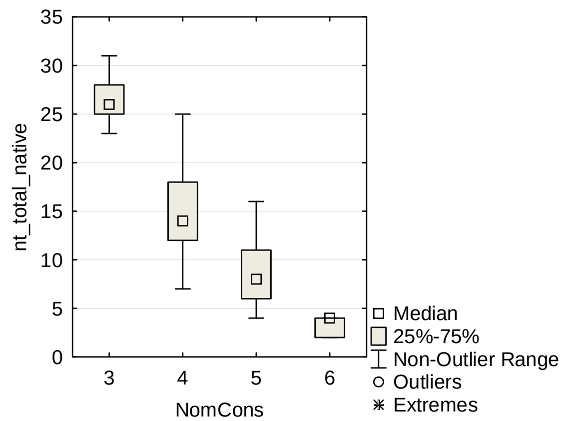
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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Median
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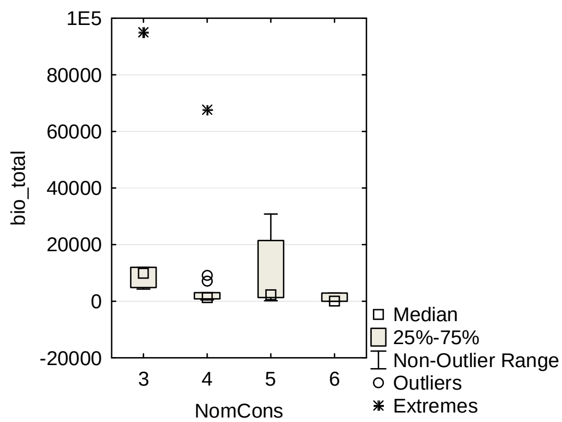
Non-Outlier Range
Outliers
Extremes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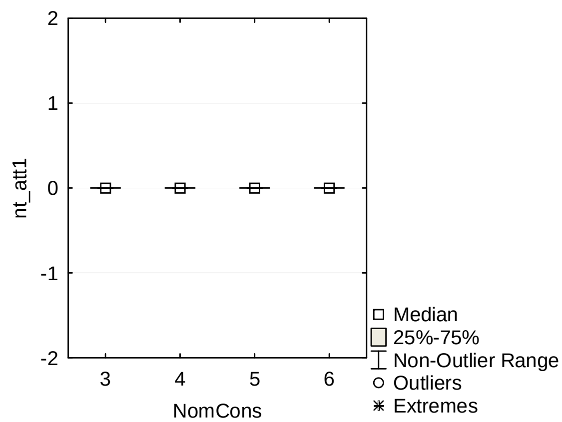
25%-75%
Non-Outlier Range
Outliers
Extremes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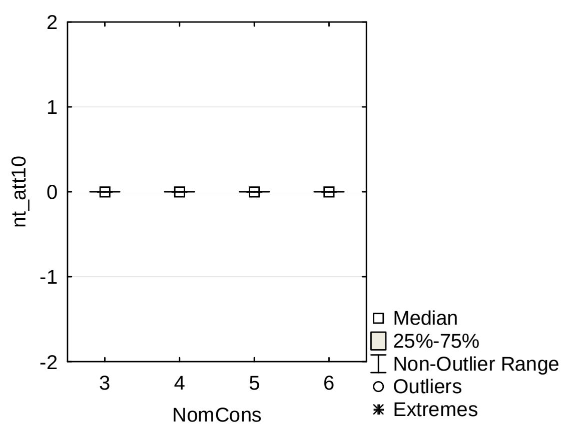
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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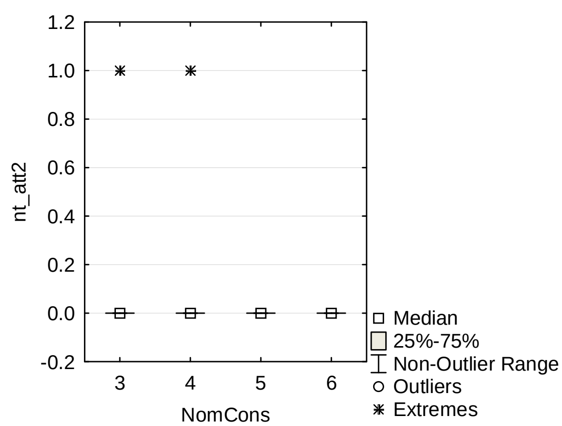
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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0.6
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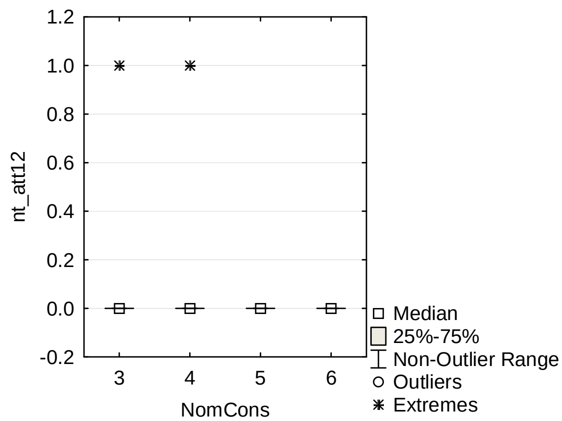
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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0.6
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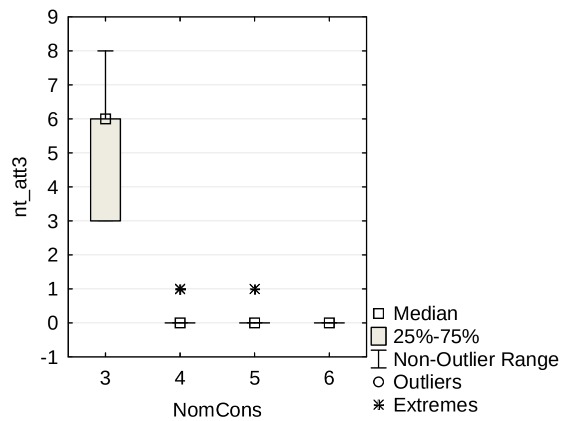
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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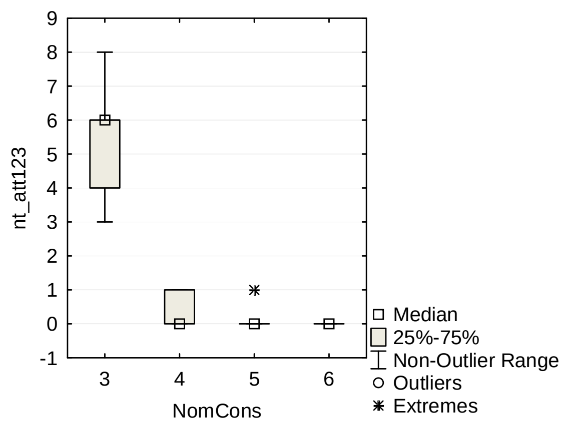
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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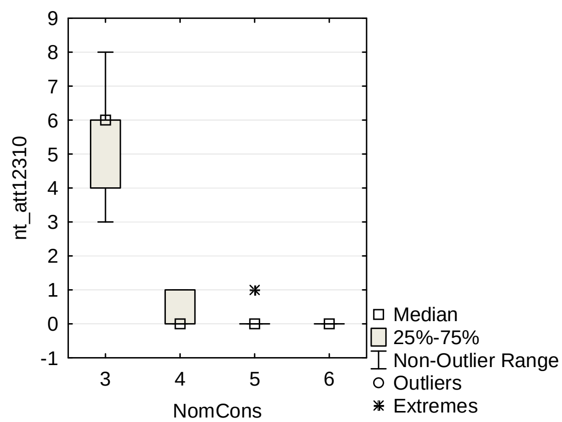
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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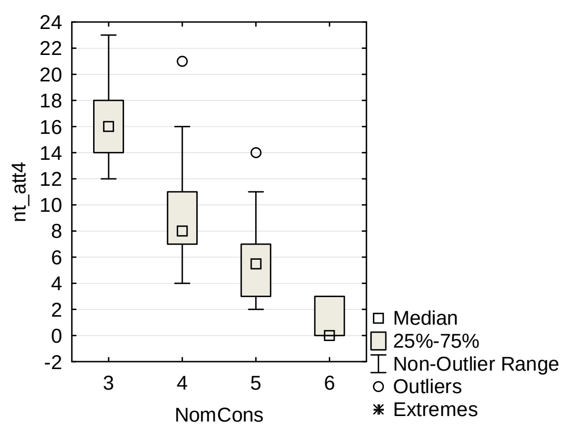
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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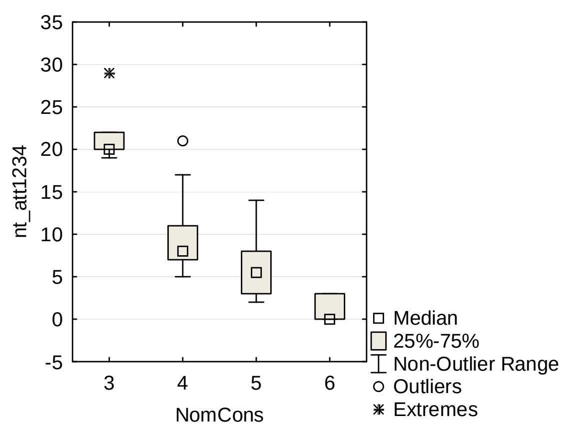
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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Median
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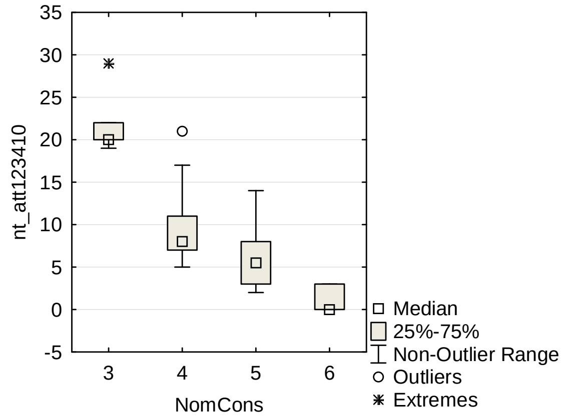
Non-Outlier Range
Outliers
Extremes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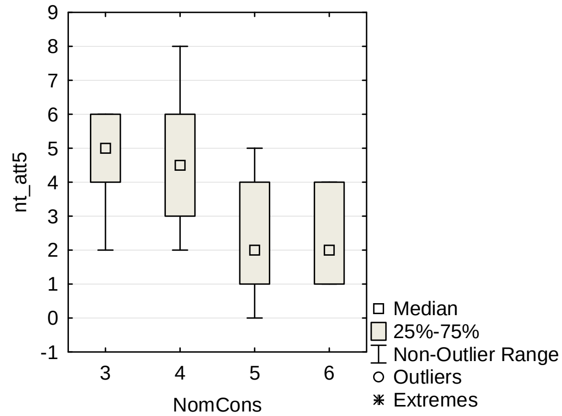
25%-75%
Non-Outlier Range
Outliers
Extremes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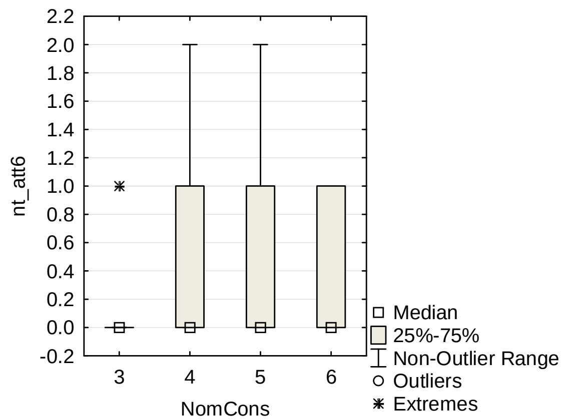
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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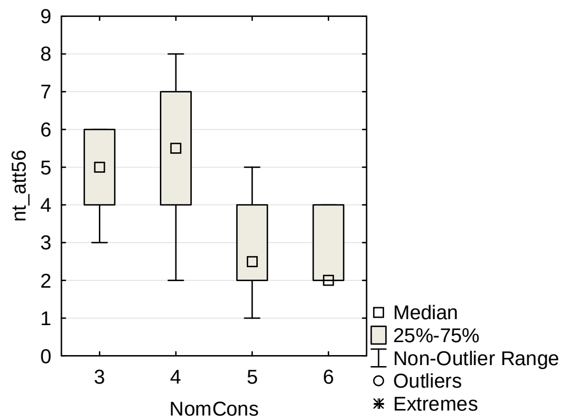
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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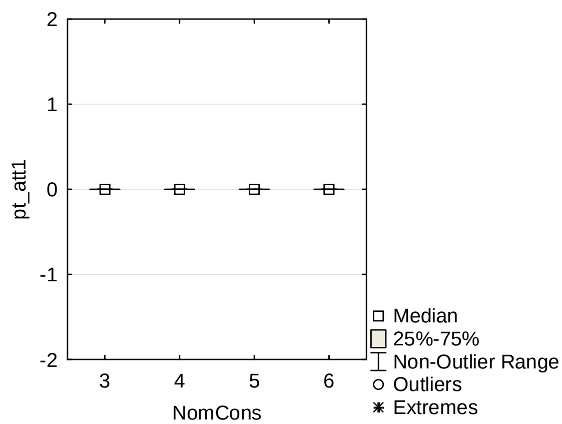
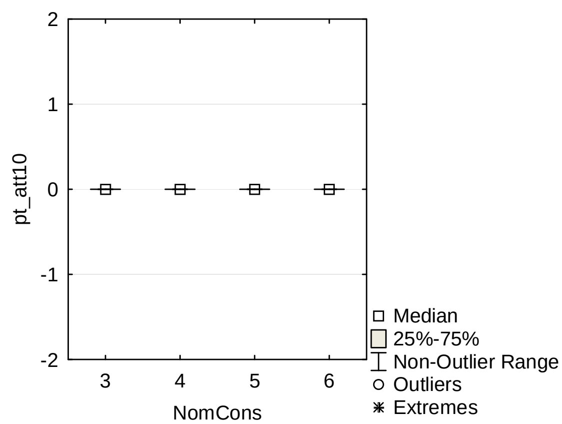
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att1
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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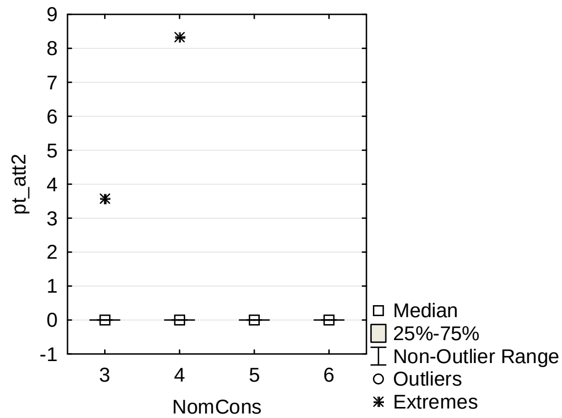
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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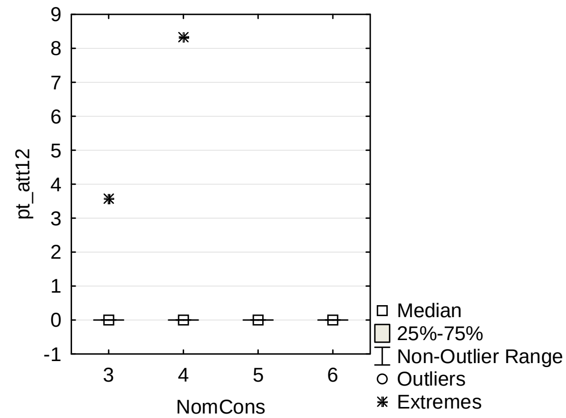
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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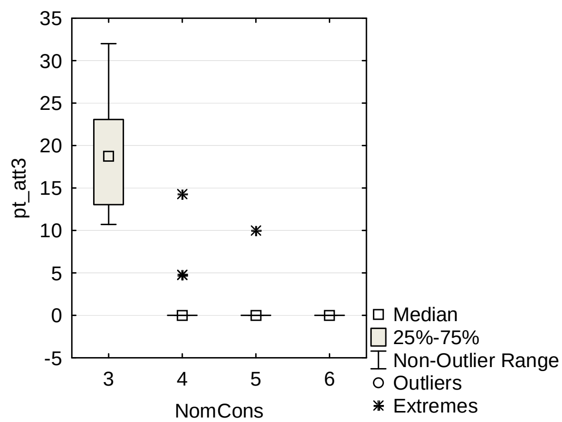
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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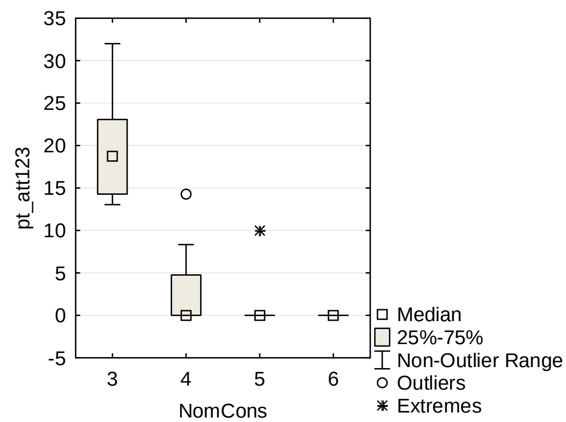
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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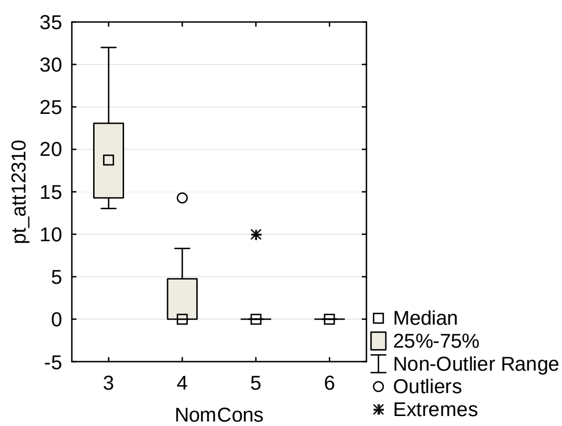
Non-Outlier Range
Outliers
Extremes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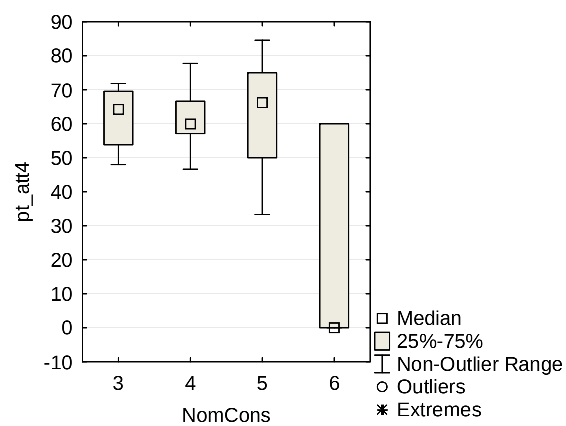
Non-Outlier Range
Outliers
Extremes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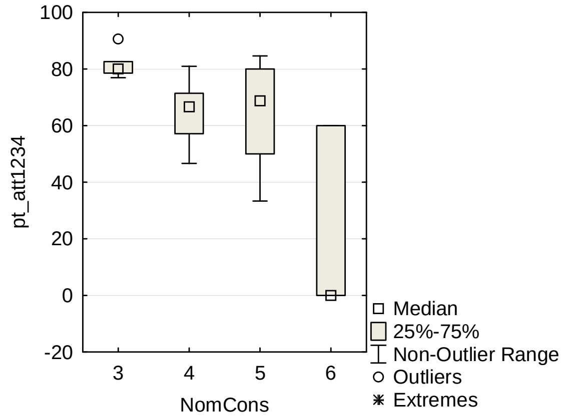
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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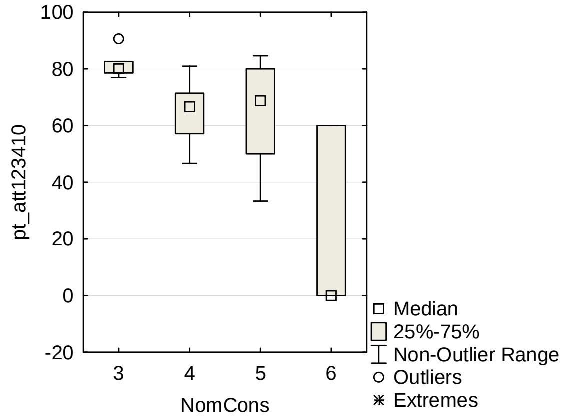
Non-Outlier Range
Outliers
Extremes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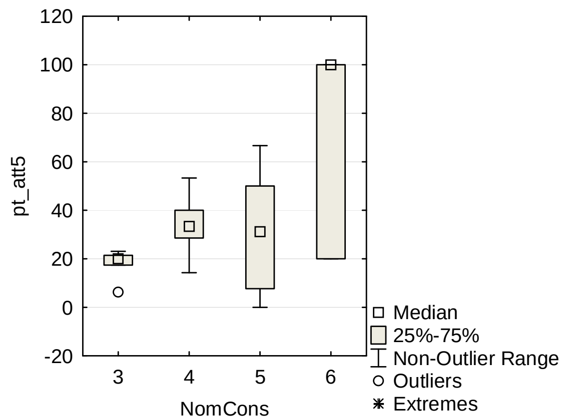
Non-Outlier Range
Outliers
Extremes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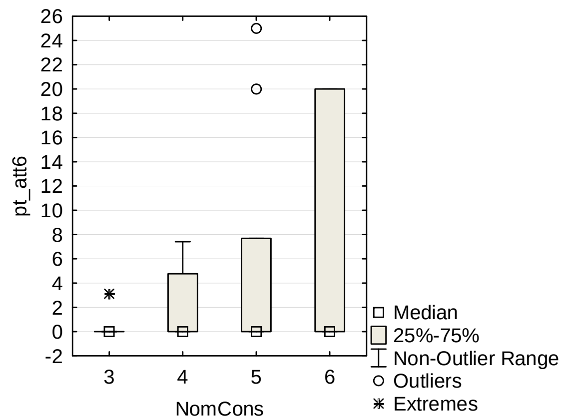
Non-Outlier Range
Outliers
Extremes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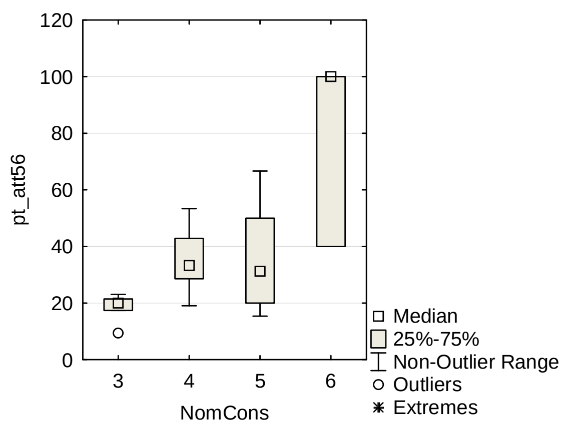
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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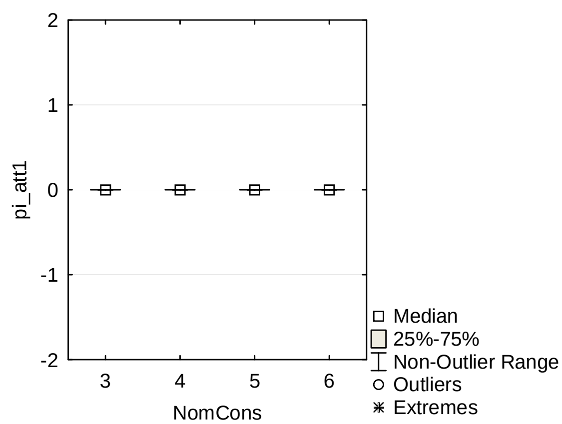
Non-Outlier Range
Outliers
Extremes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Median
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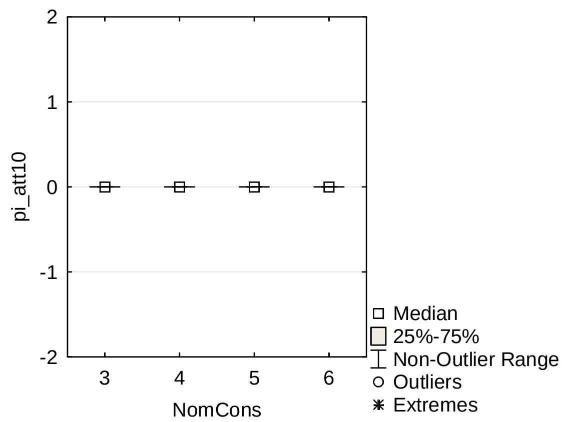
Non-Outlier Range
Outliers
Extremes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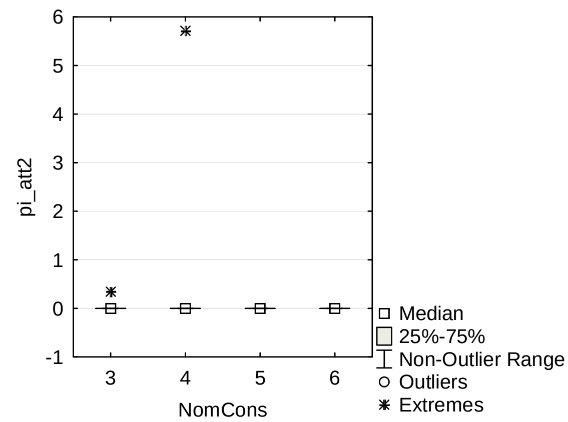
Non-Outlier Range
Outliers
Extremes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Median
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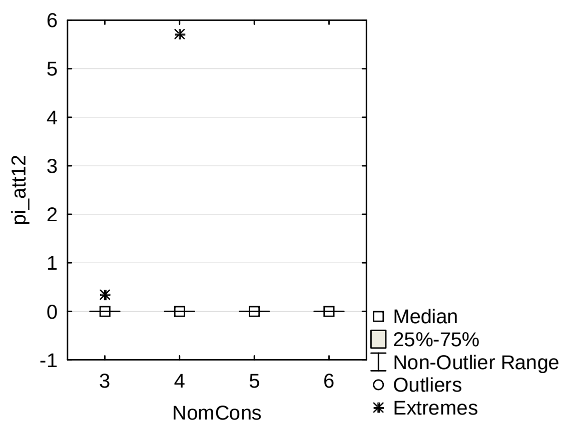
Non-Outlier Range
Outliers
Extremes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Median
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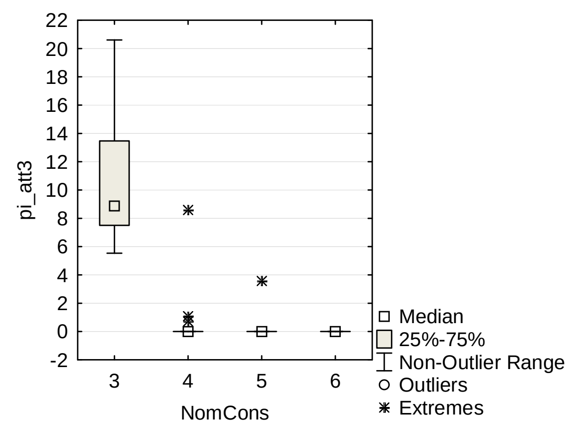
Non-Outlier Range
Outliers
Extremes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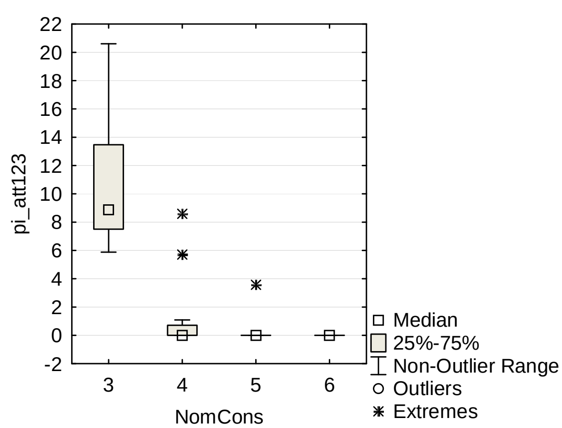
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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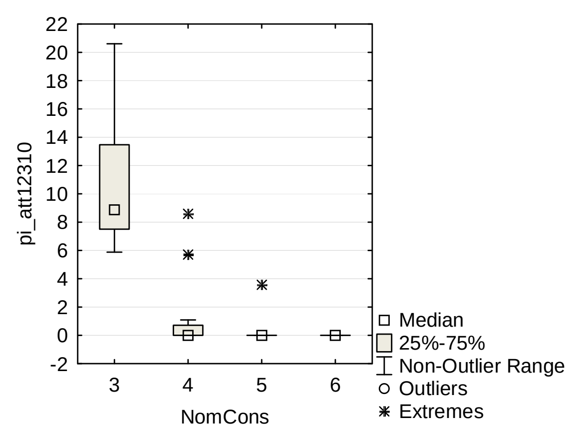
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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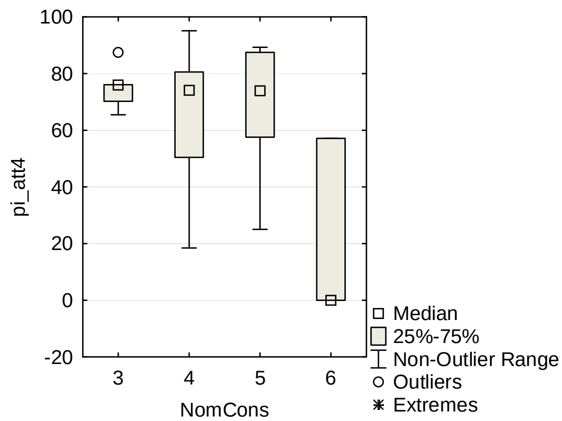
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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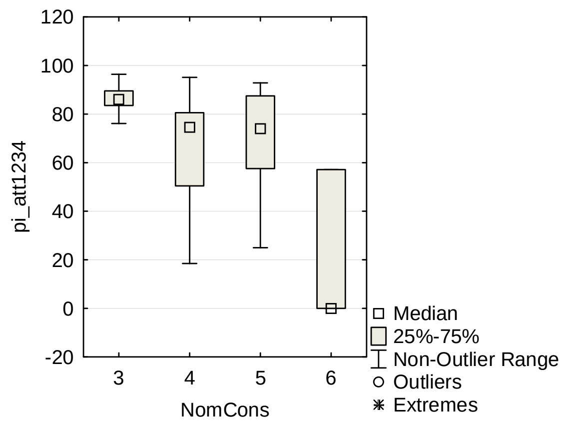
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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Median
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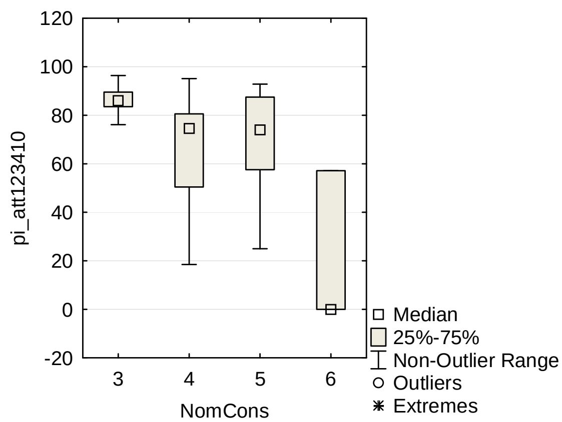
Non-Outlier Range
Outliers
Extremes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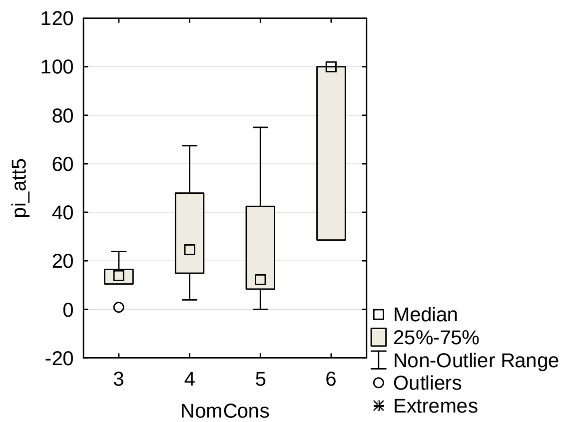
Non-Outlier Range
Outliers
Extremes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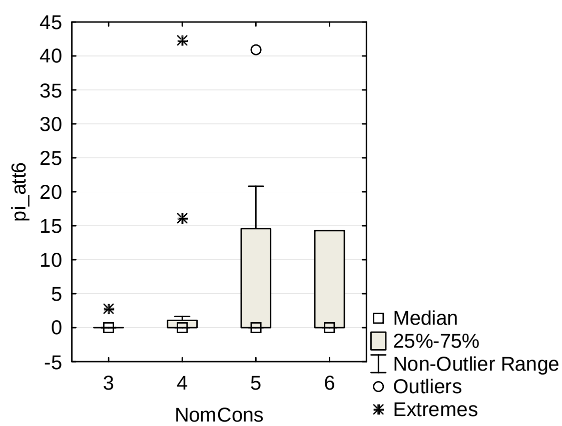
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att6
NomCons
45
40
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-5
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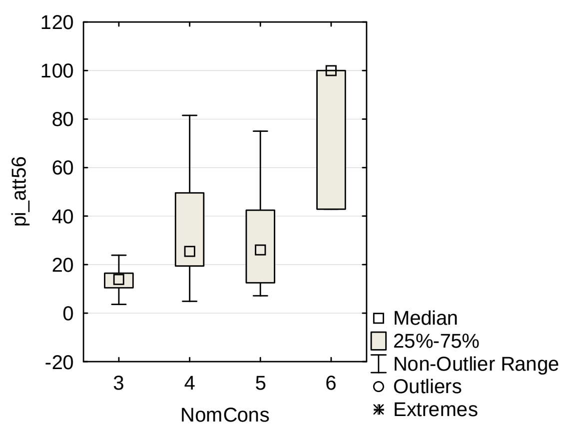
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att56
NomCons
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5
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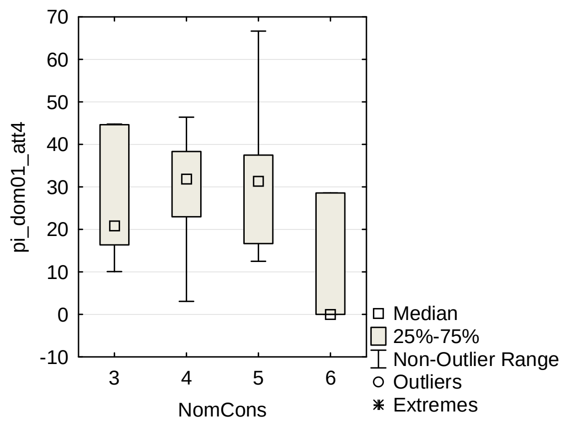
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att4
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-10
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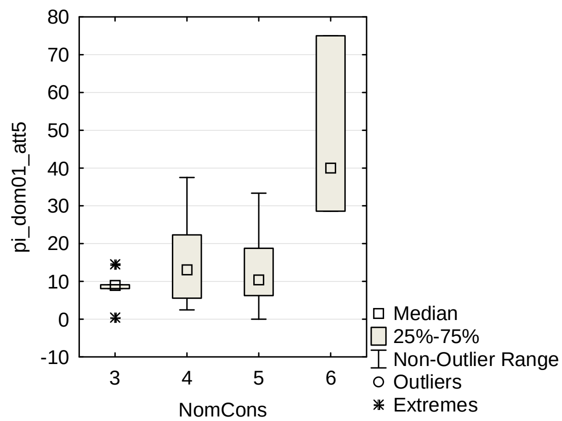
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att5
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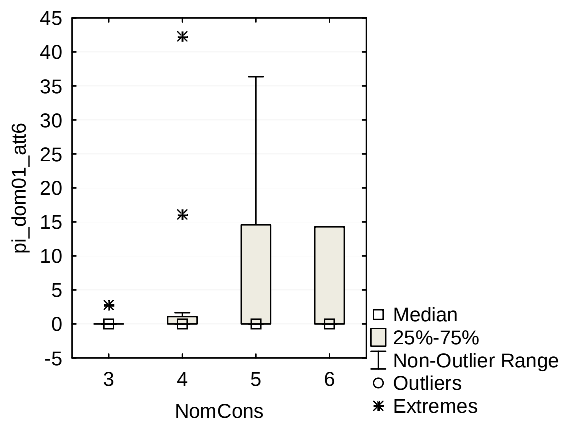
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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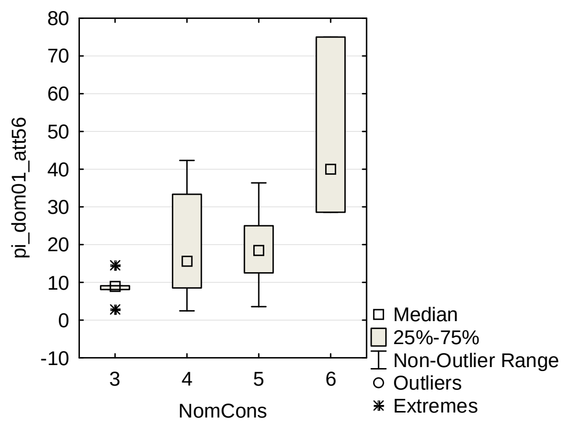
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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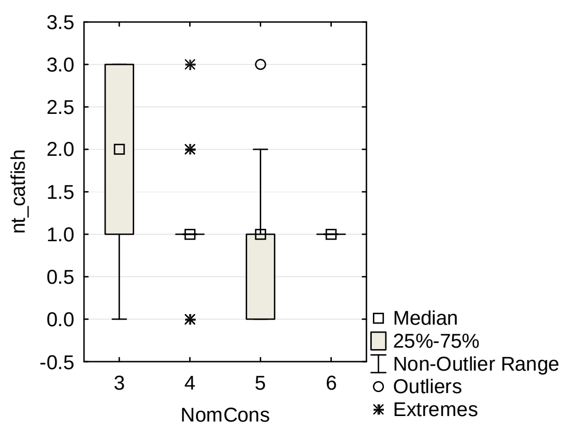
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_catfish
3.5
3.0
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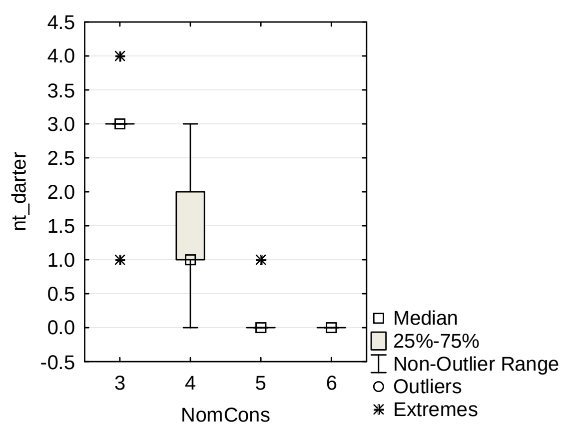
0.5
0.0
-0.5
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_darter
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
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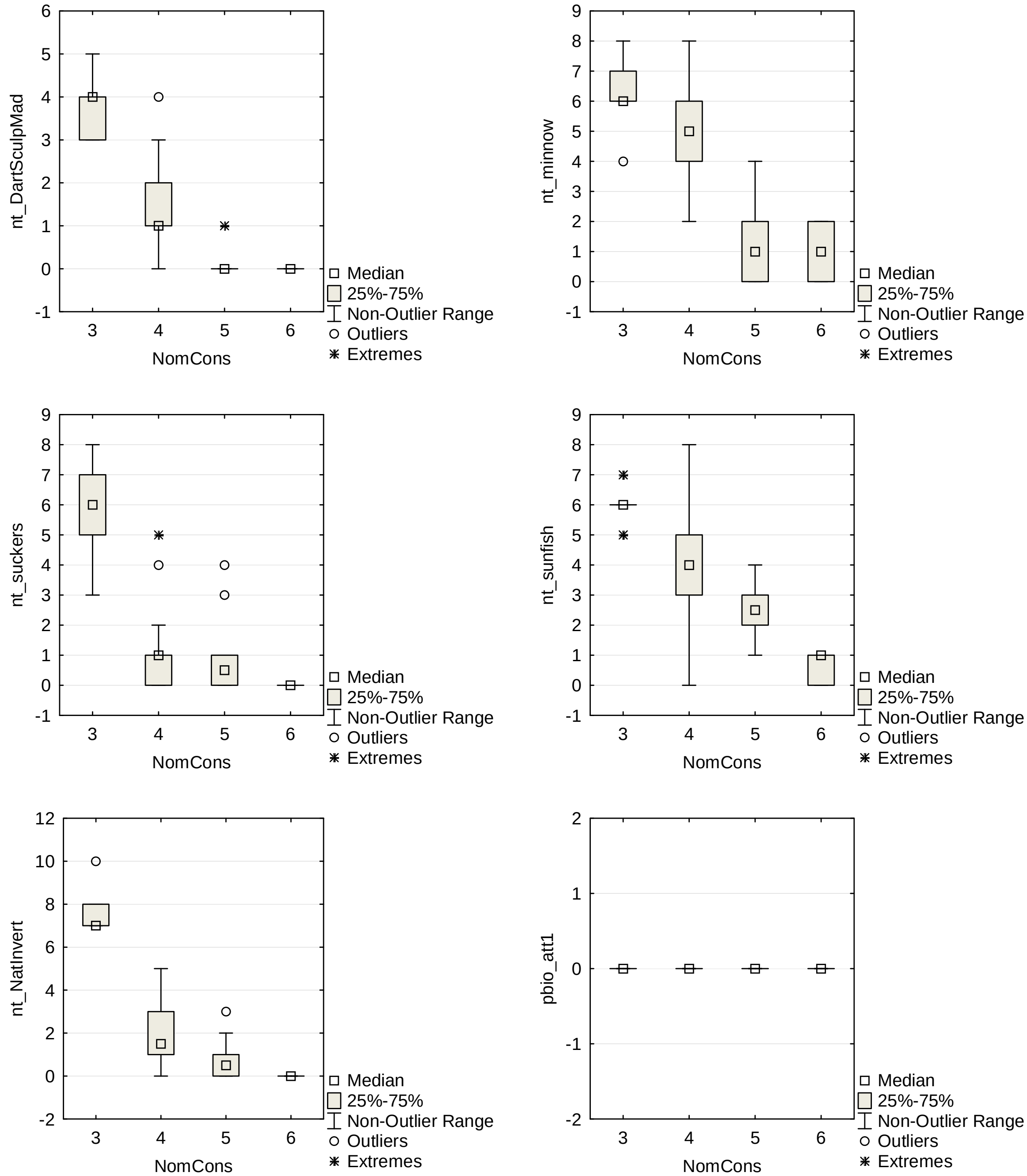
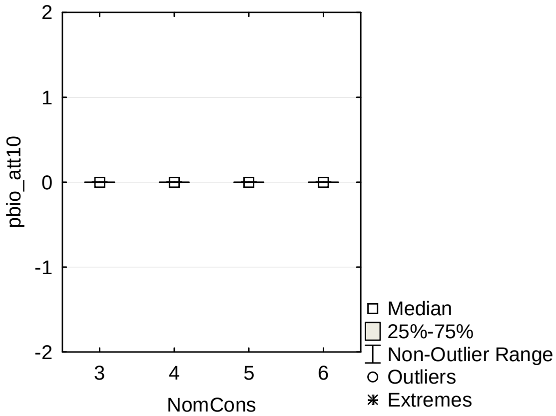
-0.5
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_DartSculpMad
NomCons
nt_minnow
NomCons
nt_suckers
NomCons
nt_sunfish
NomCons
nt_NatInvert
NomCons
pbio_att1
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att10
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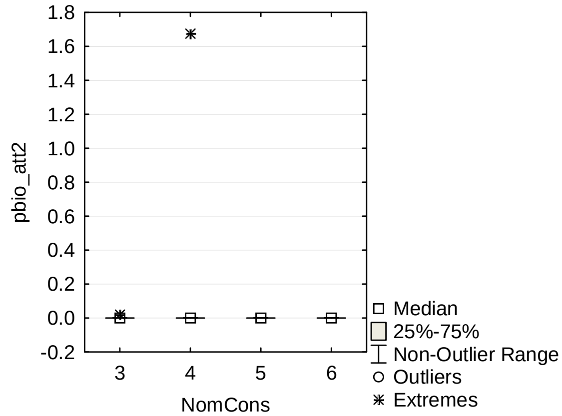
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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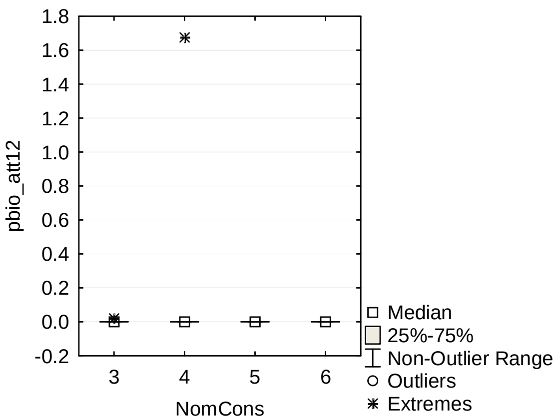
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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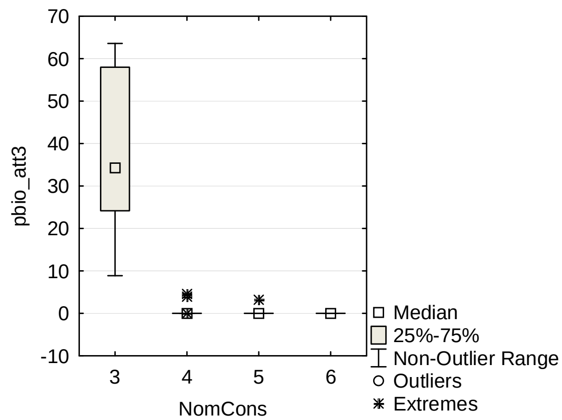
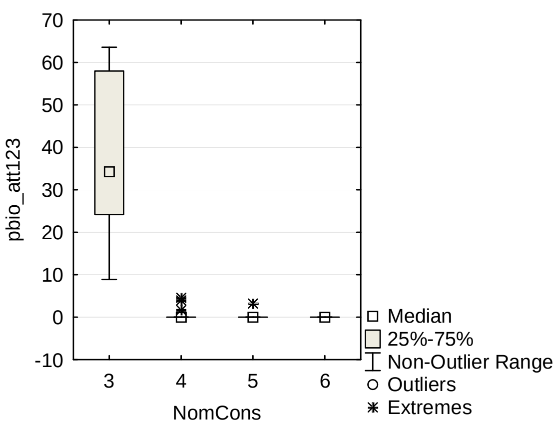
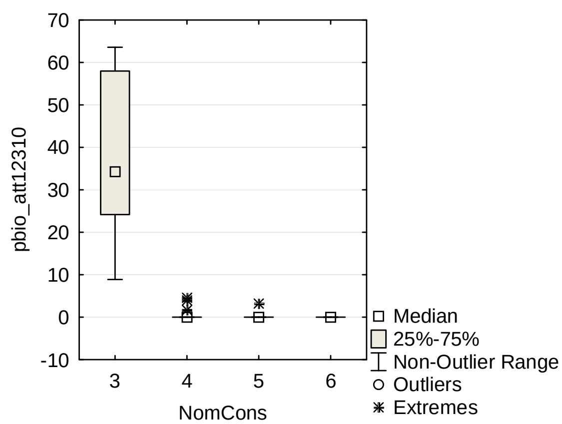
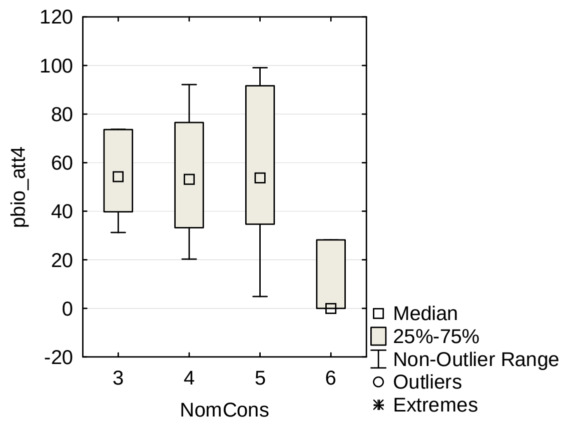
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att3
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att123
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att12310
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att4
120
100
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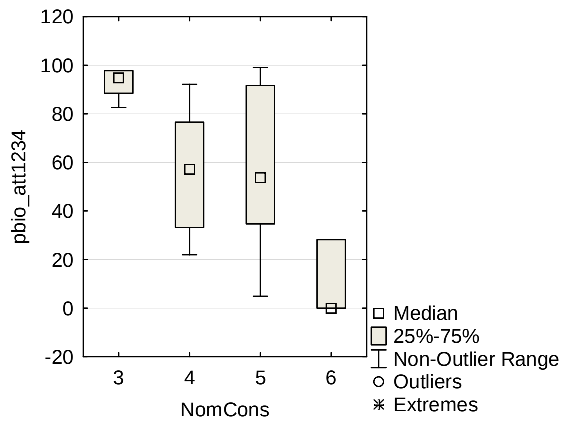
0
-20
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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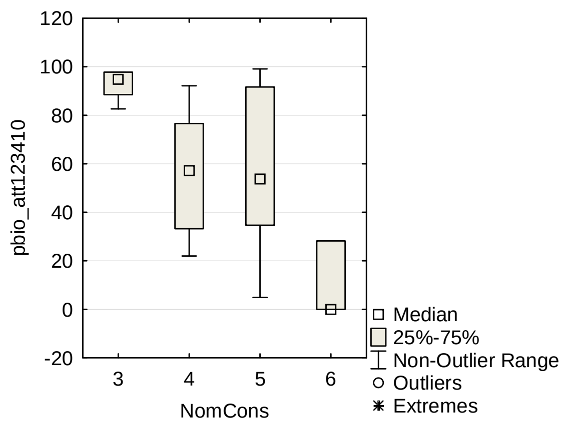
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att123410
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0
-20
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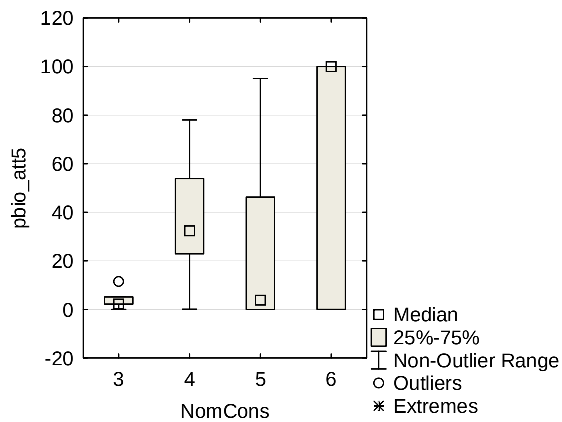
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att5
120
100
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0
-20
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4
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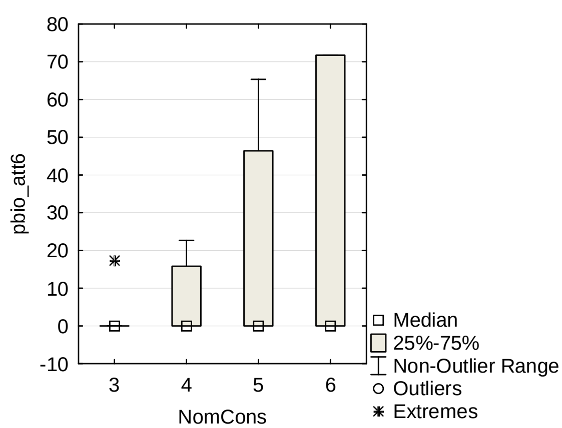
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att6
80
70
60
50
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-10
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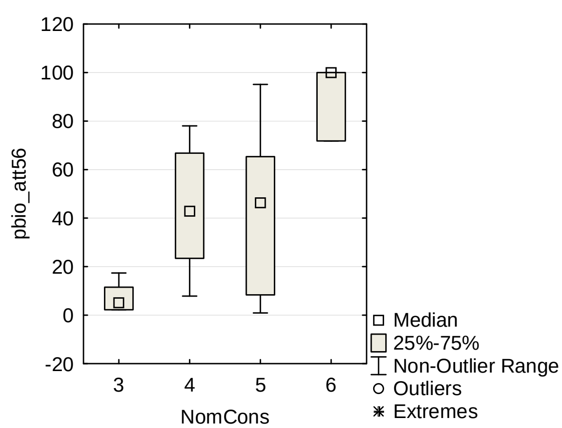
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att56
120
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-20
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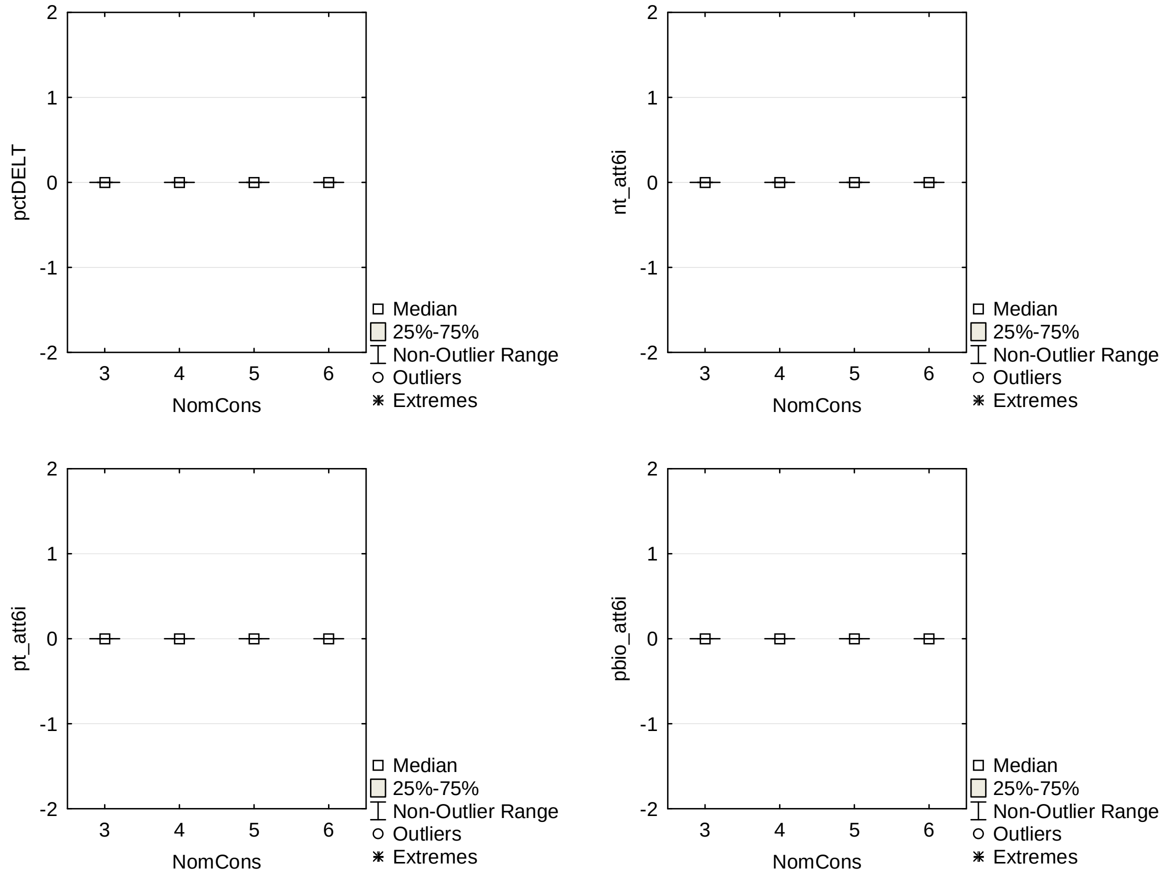
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pctDELT
nt_att6i
pt_att6i
pbio_att6i
NomCons
2
1
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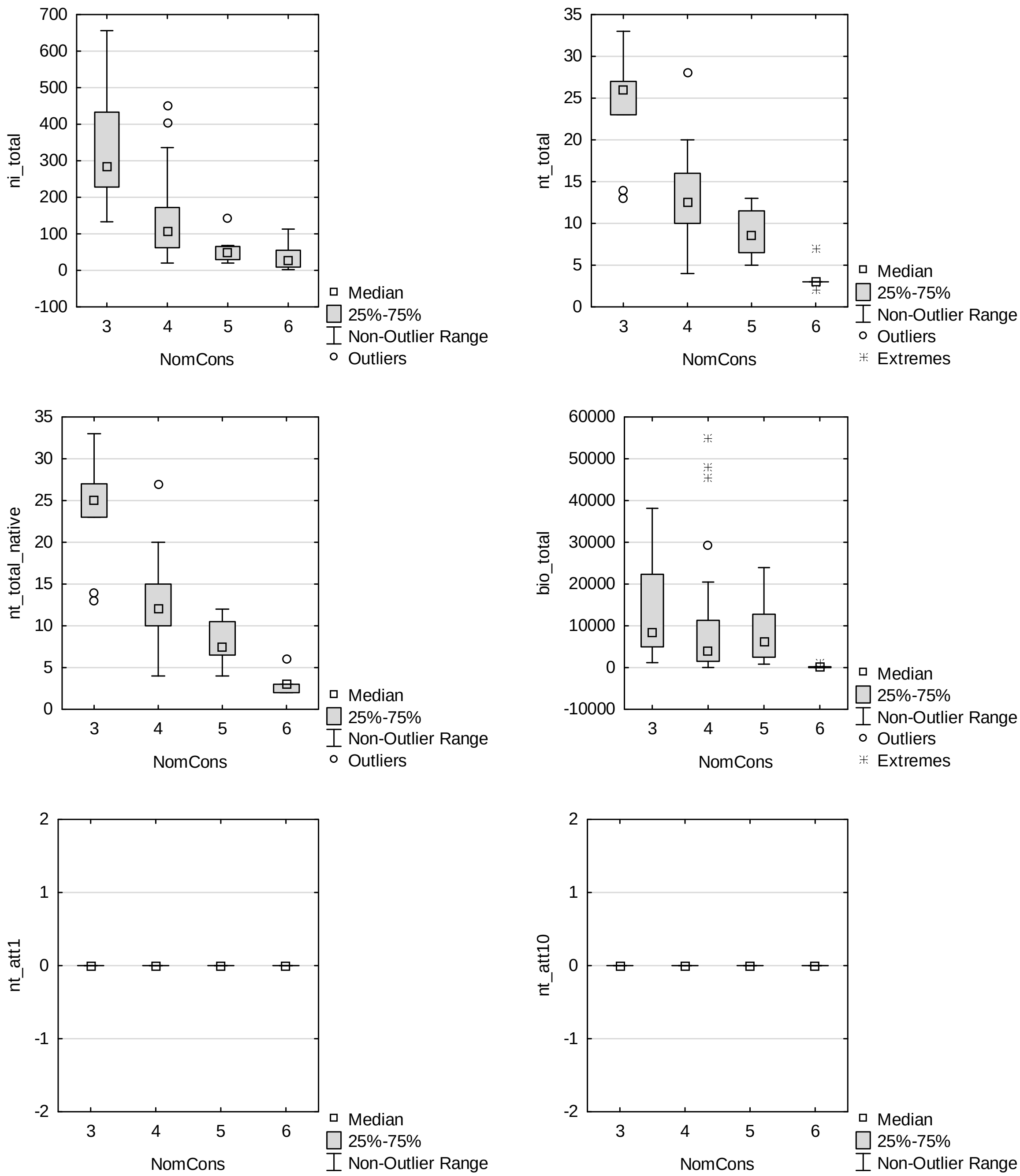
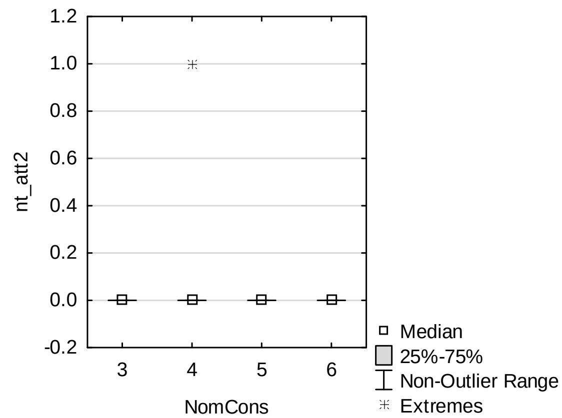
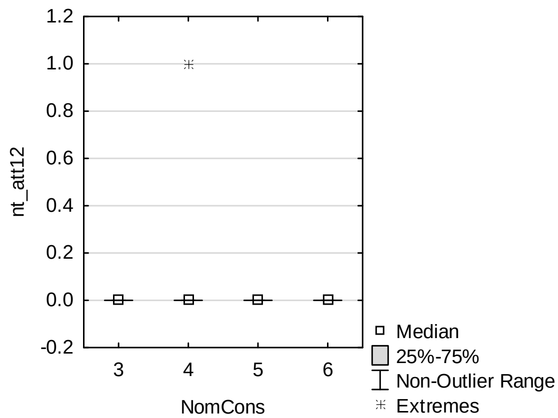
-1
-2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

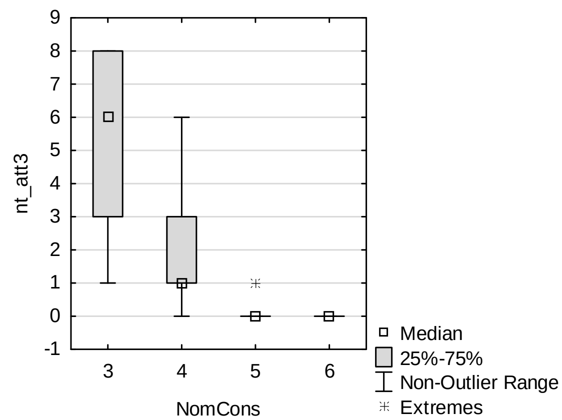
Central Corn Belt Plains

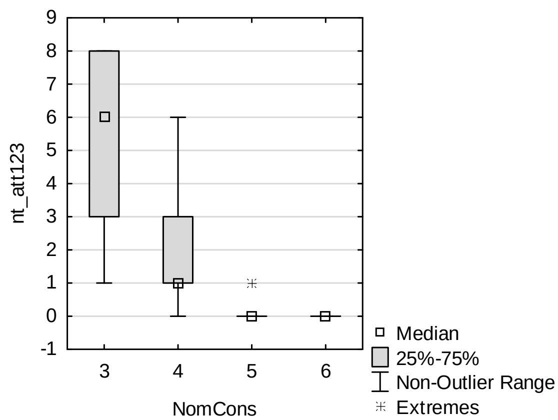


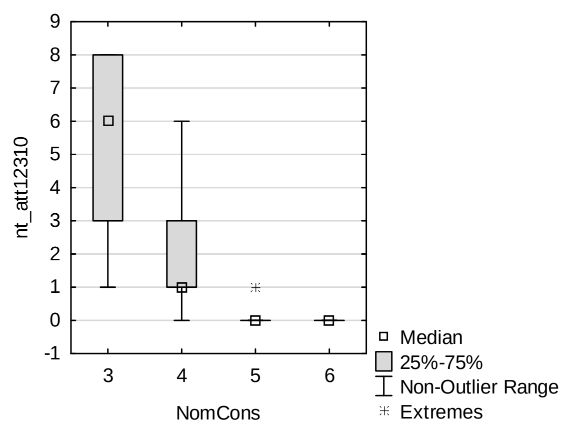
ni_total
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
nt_total
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes
nt_total_native
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
bio_total
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes
nt_att1
NomCons
Median
25%-75%
Non-Outlier Range
nt_att10
NomCons
Median
25%-75%
Non-Outlier Range

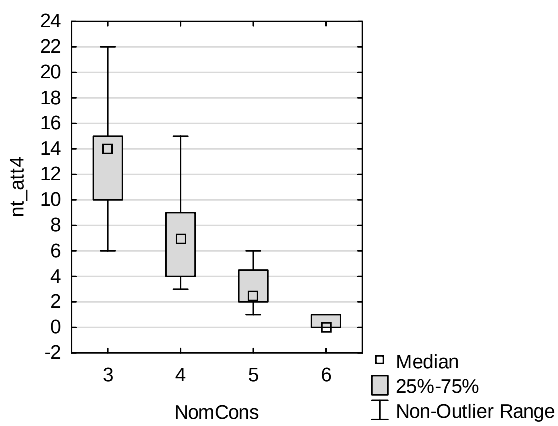

nt_att2
NomCons
Median
25%-75%
Non-Outlier Range
Extremes

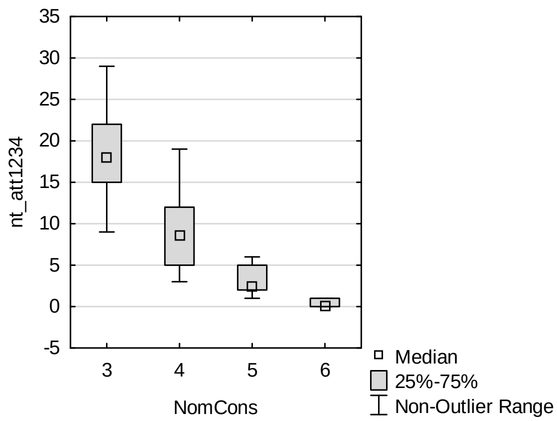

nt_att12
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


nt_att3
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


nt_att123
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


nt_att12310
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


nt_att4
NomCons
Median
25%-75%
Non-Outlier Range


nt_att1234
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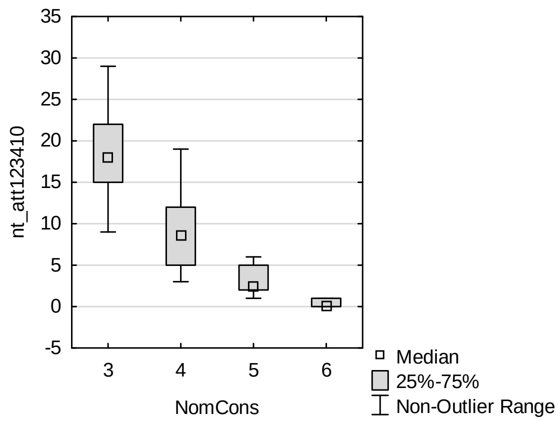
6
NomCons
Median
25%-75%
Non-Outlier Range


nt_att123410
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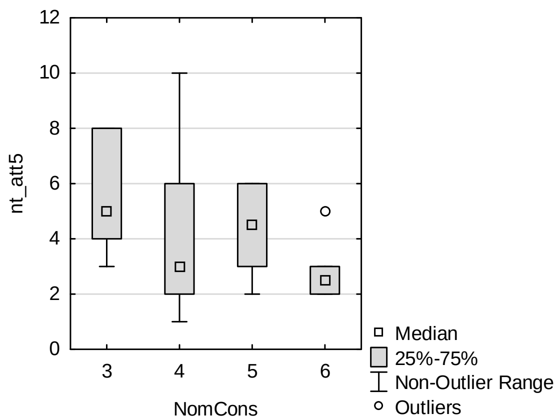
6
NomCons
Median
25%-75%
Non-Outlier Range


nt_att5
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5
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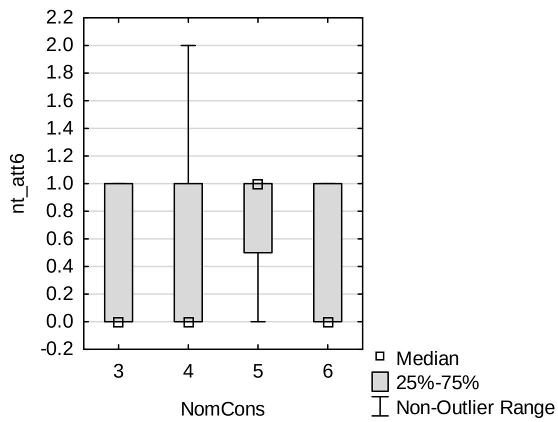
NomCons
Median
25%-75%
Non-Outlier Range
Outliers


nt_att6
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0.0
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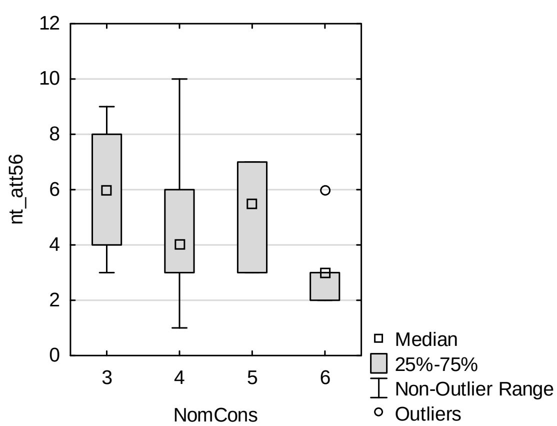
6
NomCons
Median
25%-75%
Non-Outlier Range


nt_att56
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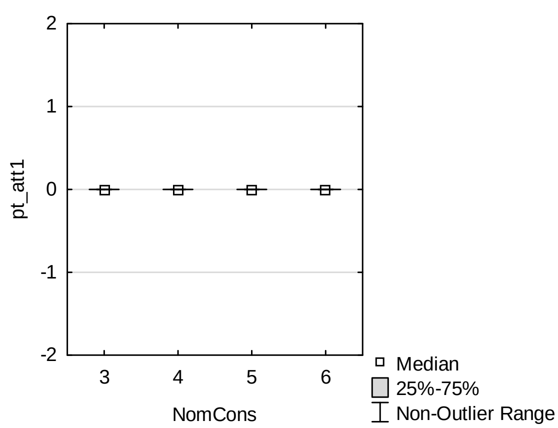
NomCons
Median
25%-75%
Non-Outlier Range
Outliers


pt_att1
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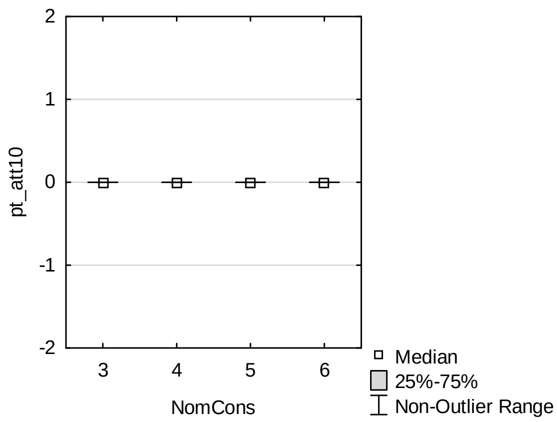
6
NomCons
Median
25%-75%
Non-Outlier Range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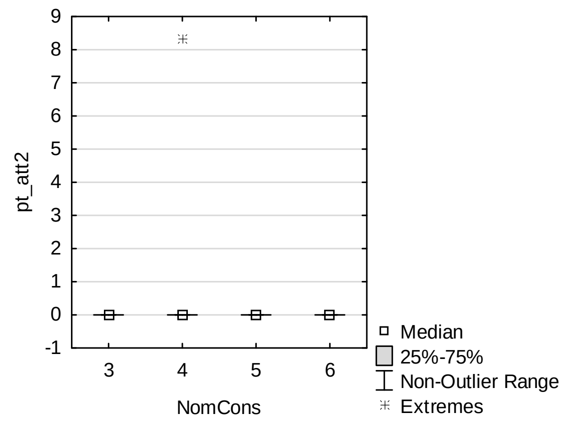
NomCons
Median
25%-75%
Non-Outlier Range


pt_att2
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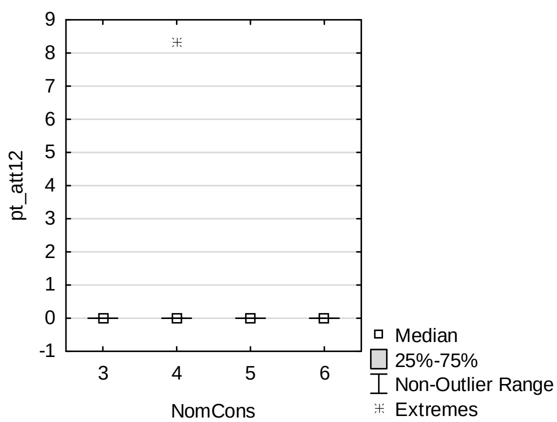
NomCons
Median
25%-75%
Non-Outlier Range
Extremes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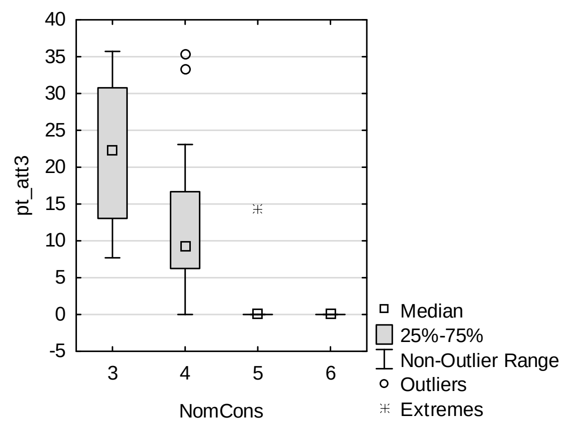
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


pt_att3
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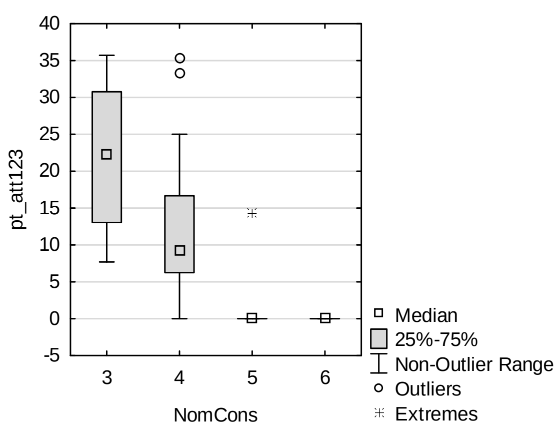
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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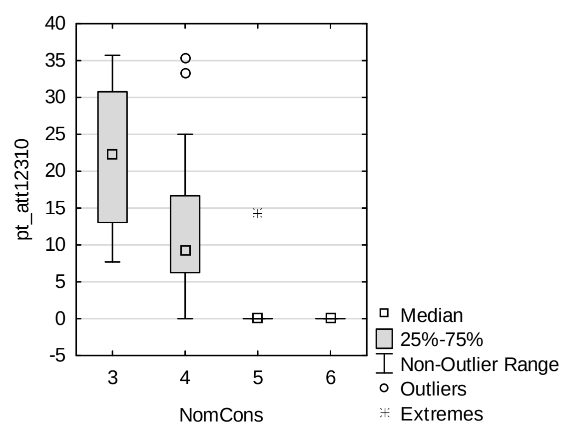
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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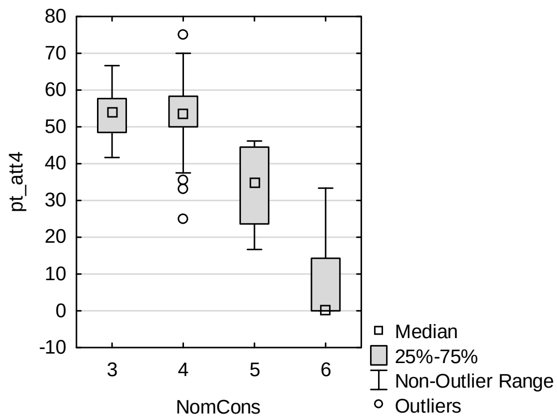
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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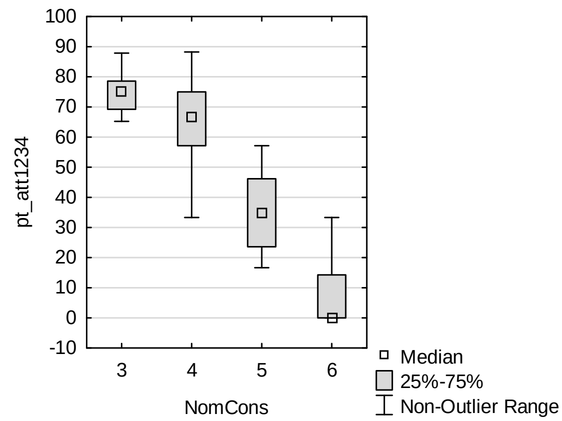
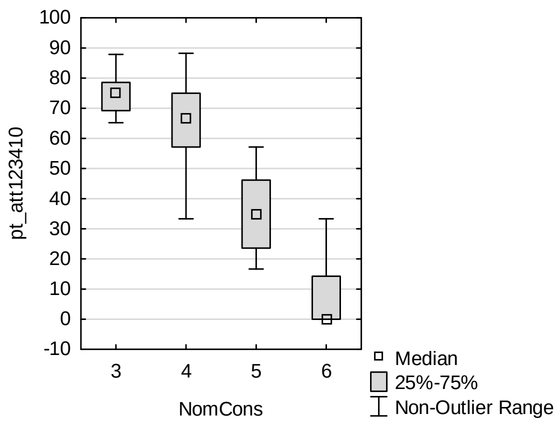
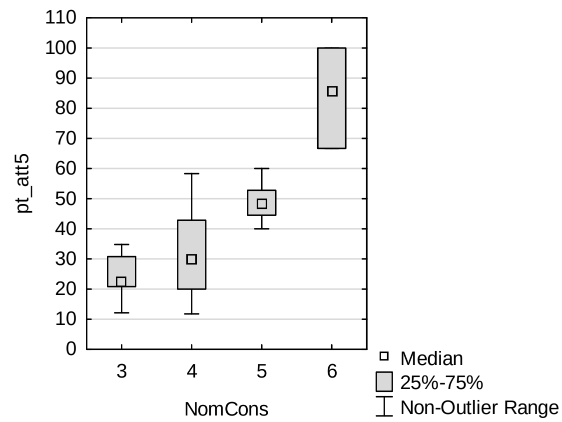
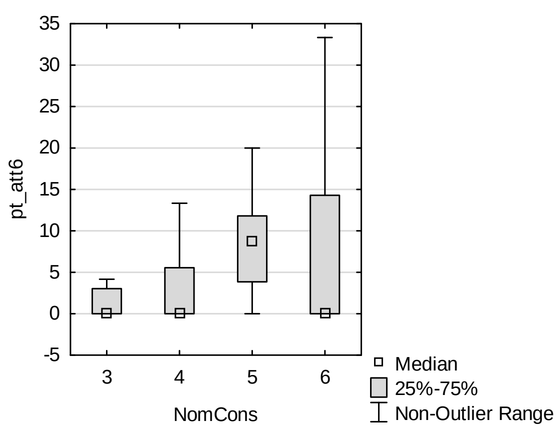
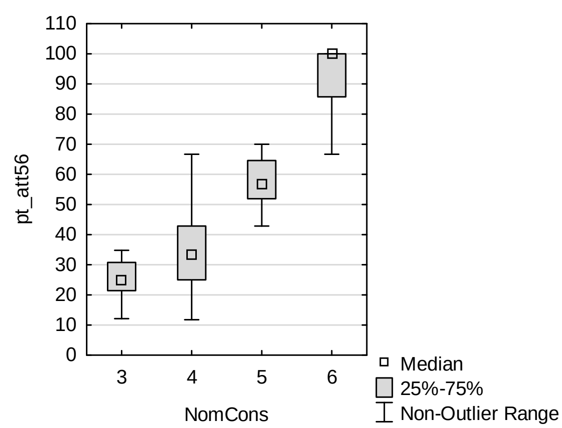
NomCons
Median
25%-75%
Non-Outlier Range
Outliers

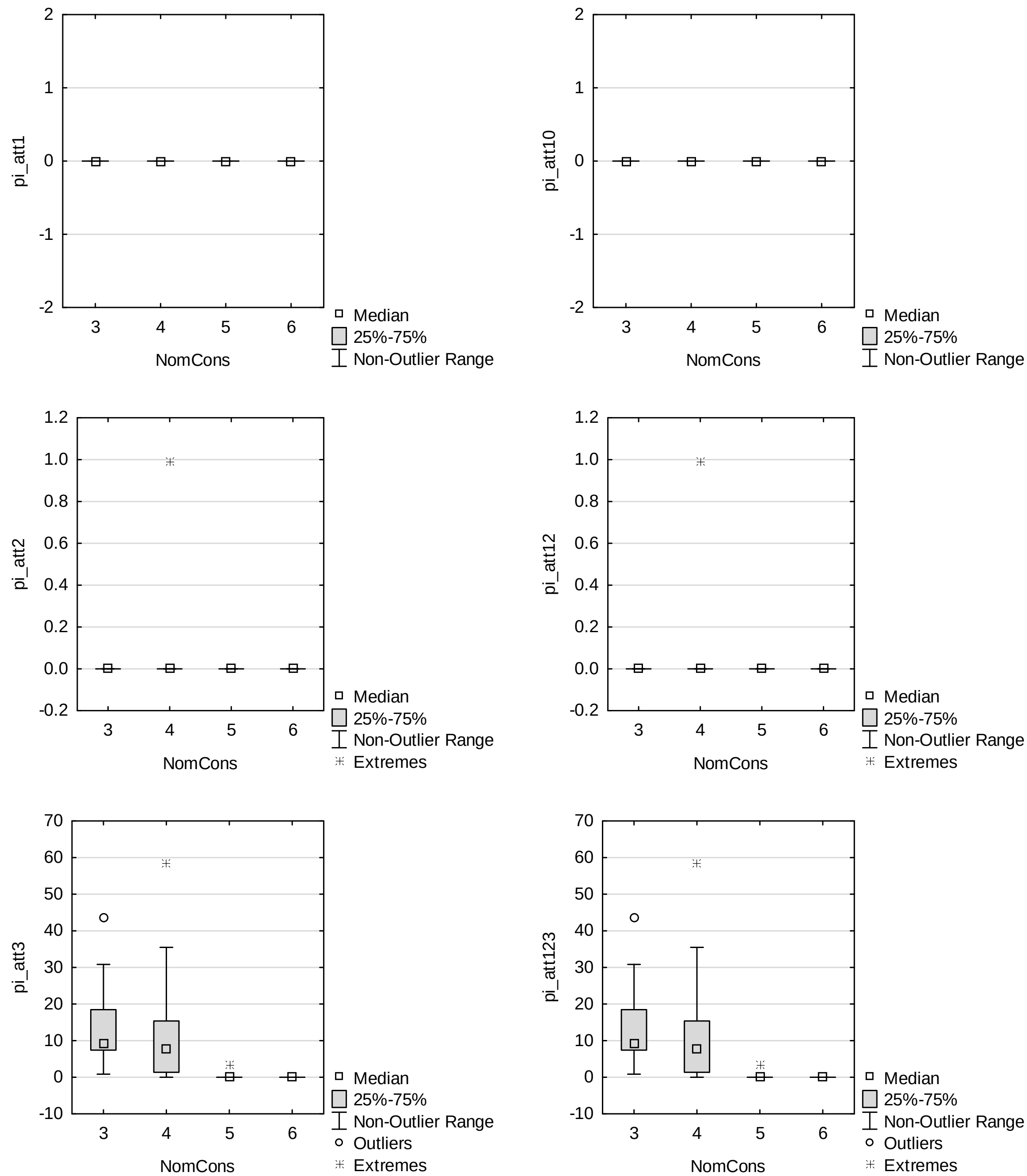

pt_att1234
NomCons
Median
25%-75%
Non-Outlier Range

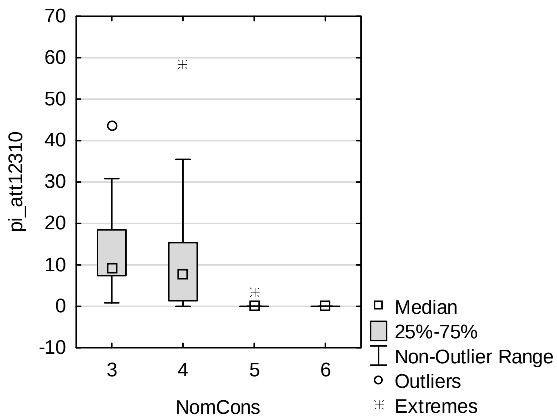

pt_att123410
NomCons
Median
25%-75%
Non-Outlier Range


pt_att5
NomCons
Median
25%-75%
Non-Outlier Range


pt_att6
NomCons
Median
25%-75%
Non-Outlier Range


pt_att56
NomCons
Median
25%-75%
Non-Outlier Range


pi_att1
NomCons
pi_att10
NomCons
pi_att2
NomCons
pi_att12
NomCons
pi_att3
NomCons
pi_att123
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att12310
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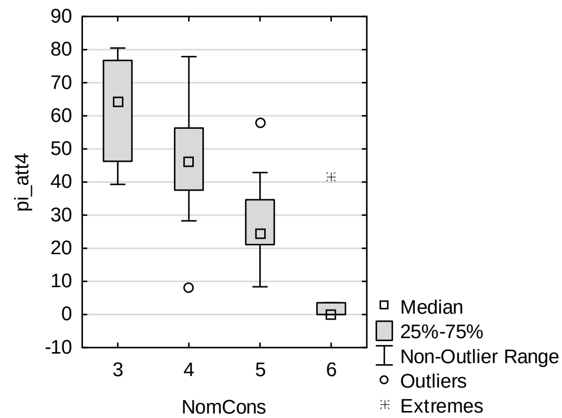
-10
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att4
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-10
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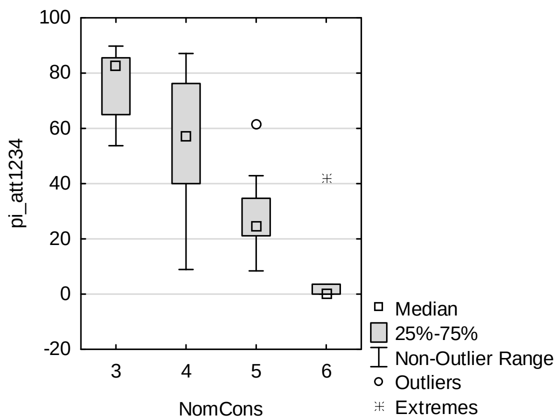
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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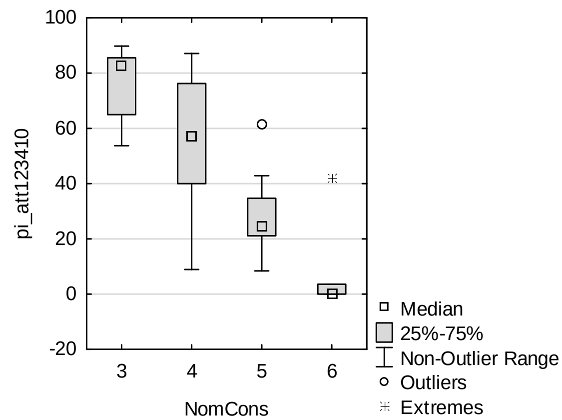
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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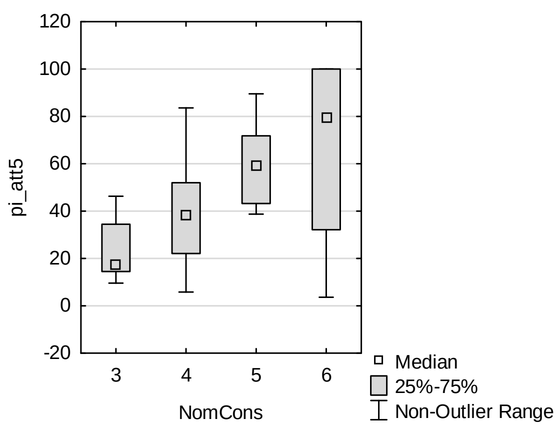
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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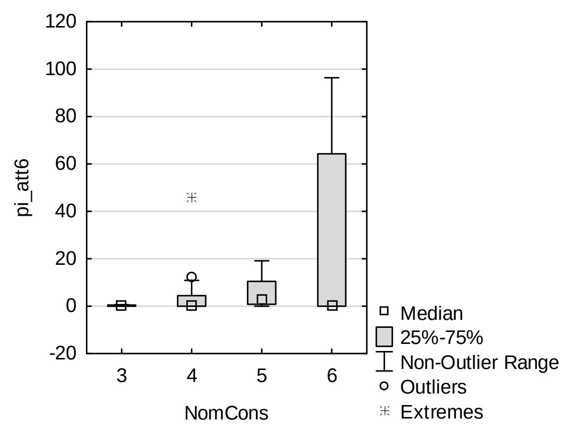
NomCons
Median
25%-75%
Non-Outlier Range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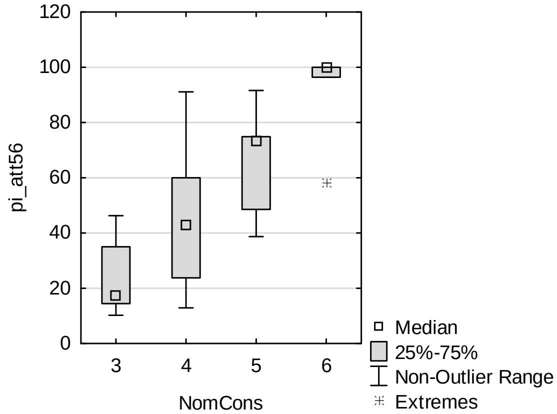
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
Median
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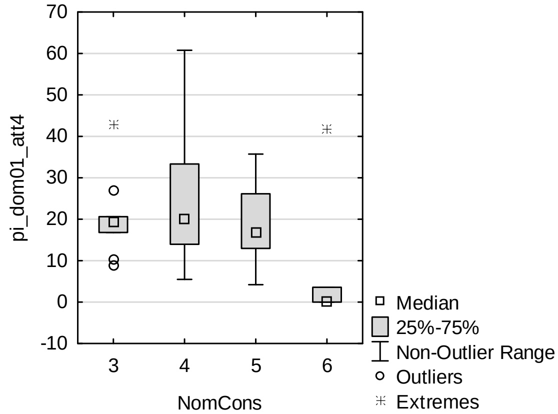
Non-Outlier Range
Extremes


pi_dom01_att4
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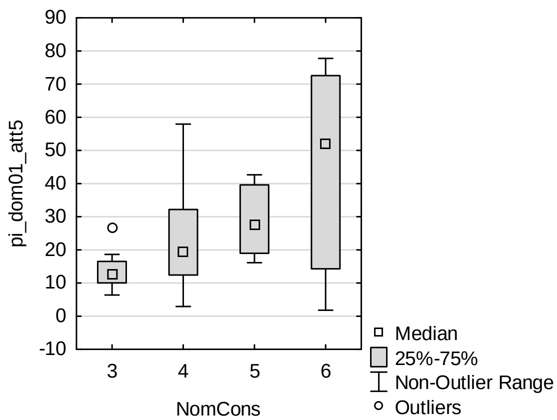
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att5
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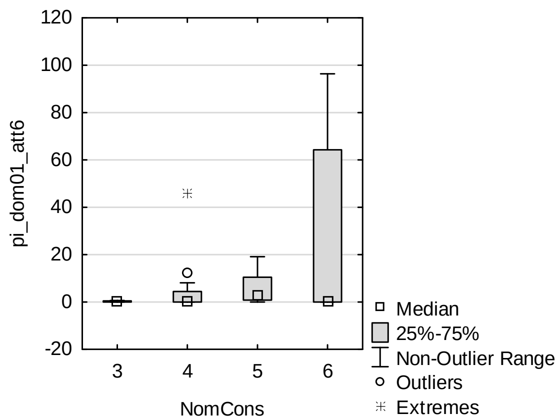
NomCons
Median
25%-75%
Non-Outlier Range
Outliers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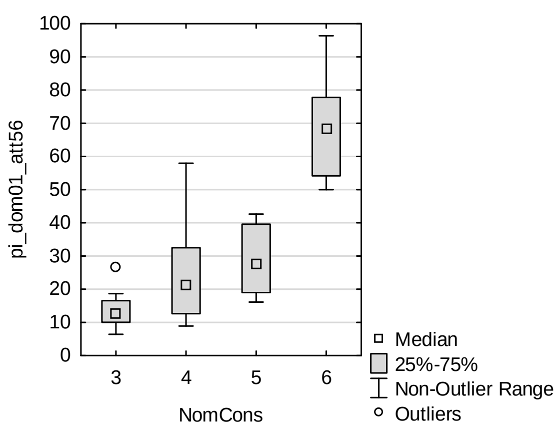
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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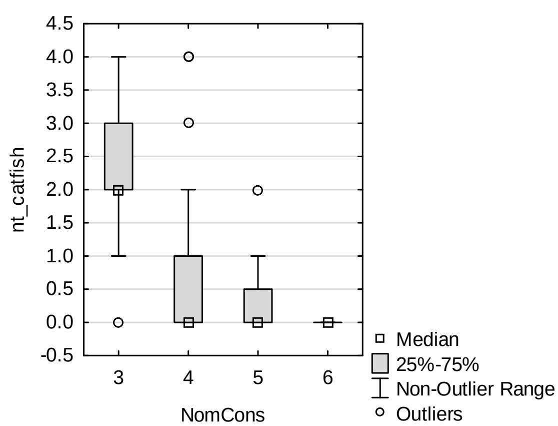
NomCons
Median
25%-75%
Non-Outlier Range
Outliers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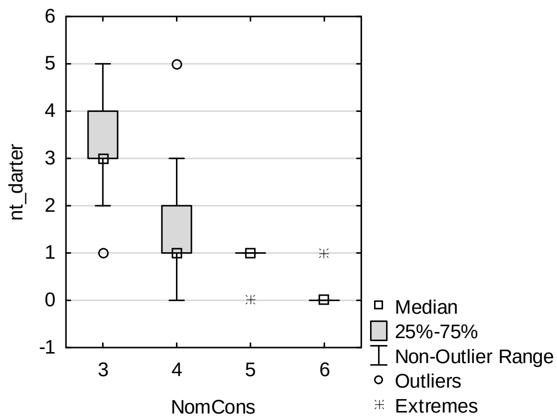
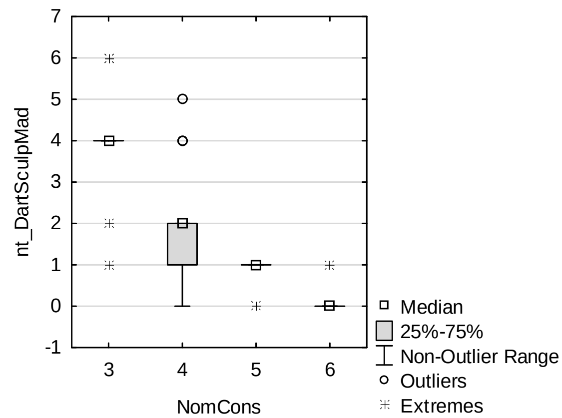
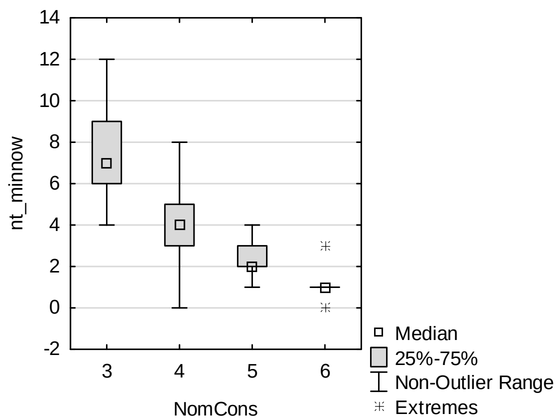
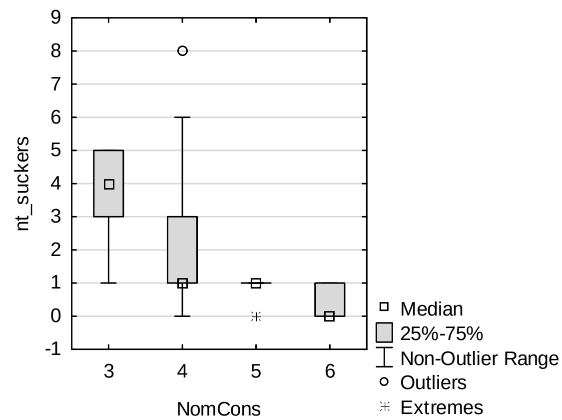
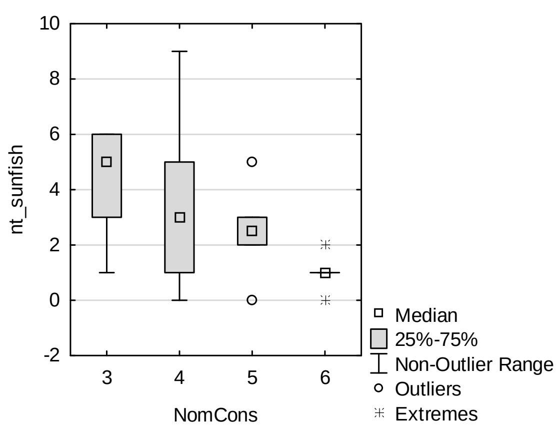
NomCons
Median
25%-75%
Non-Outlier Range
Outliers


nt_darter
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_DartSculpMad
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_minnow
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


nt_suckers
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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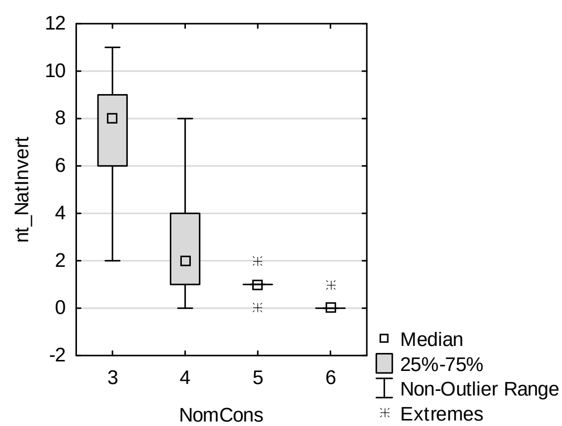
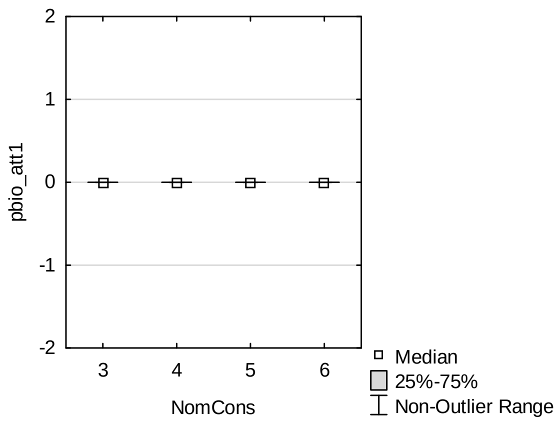
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_NatInvert
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


pbio_att1
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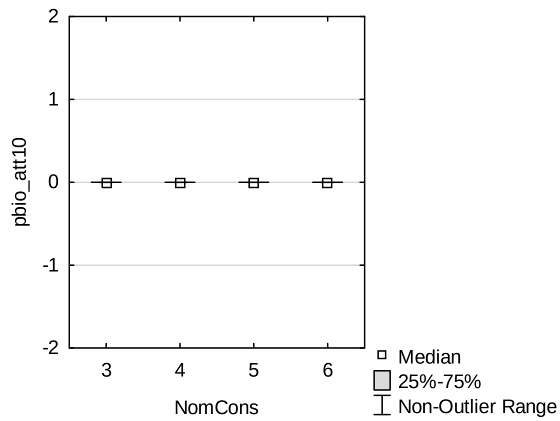
6
NomCons
Median
25%-75%
Non-Outlier Range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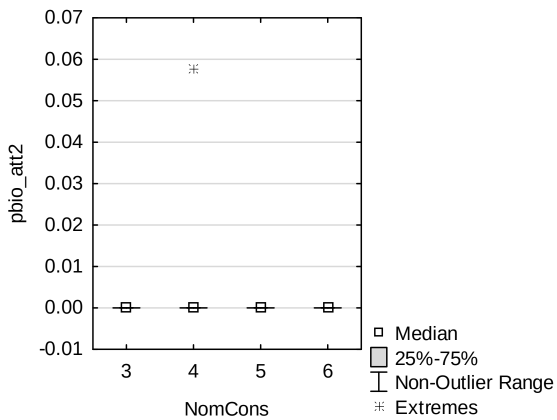
6
NomCons
Median
25%-75%
Non-Outlier Range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0.05
0.04
0.03
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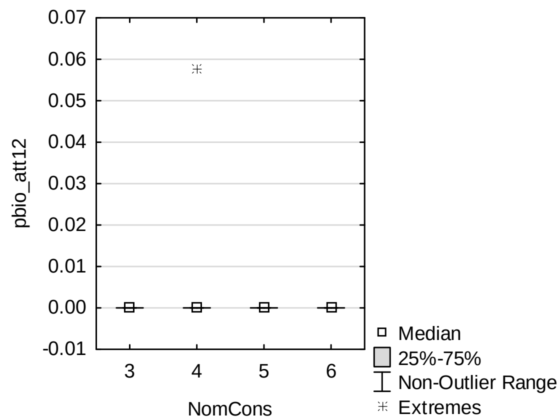
NomCons
Median
25%-75%
Non-Outlier Range
Extremes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0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
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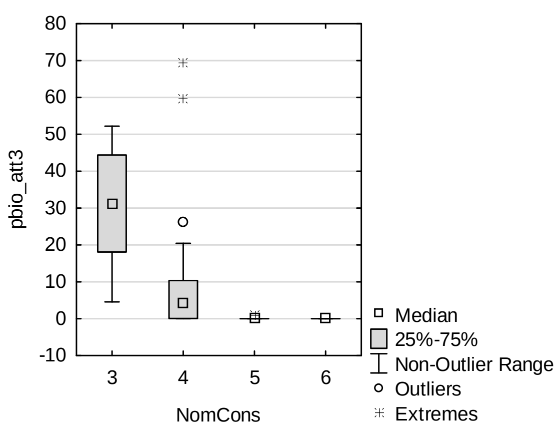
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


pbio_att3
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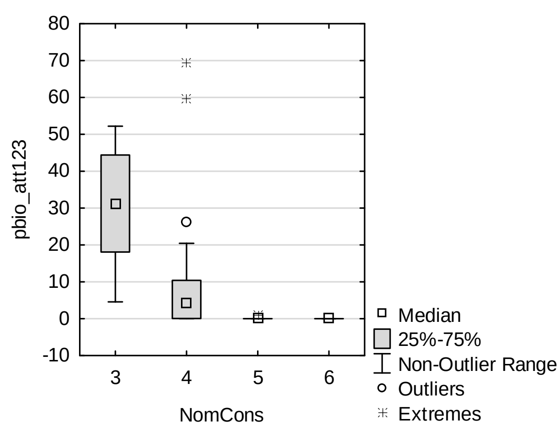
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att123
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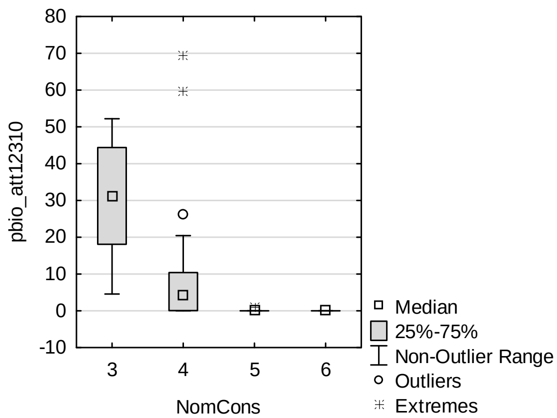
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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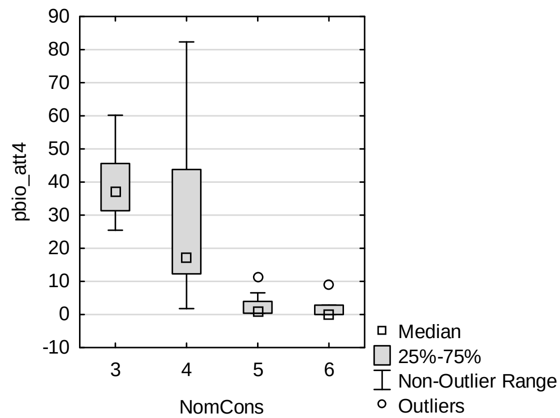
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att4
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5
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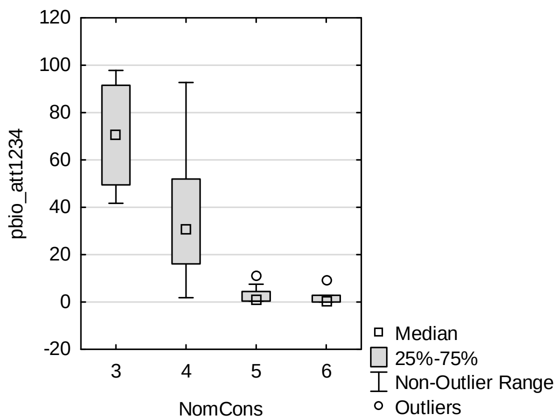
NomCons
Median
25%-75%
Non-Outlier Range
Outliers


pbio_att1234
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0
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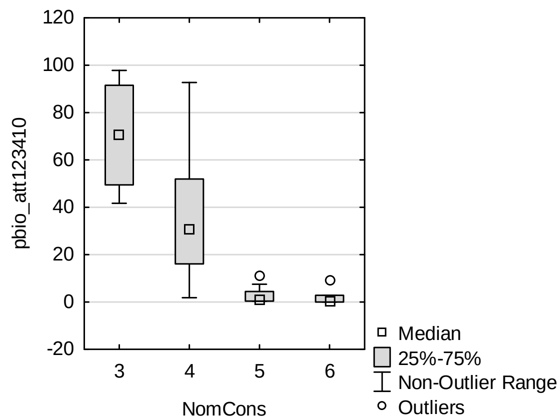
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers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-20
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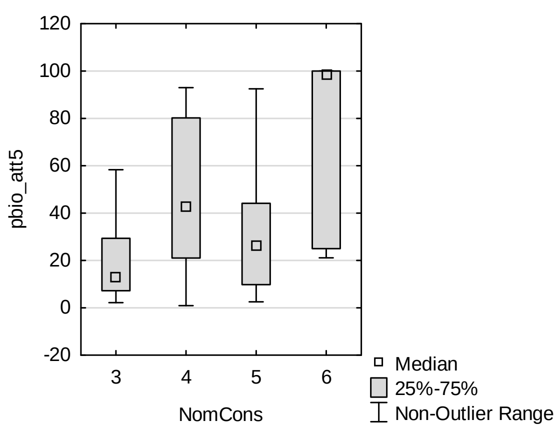
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers


pbio_att5
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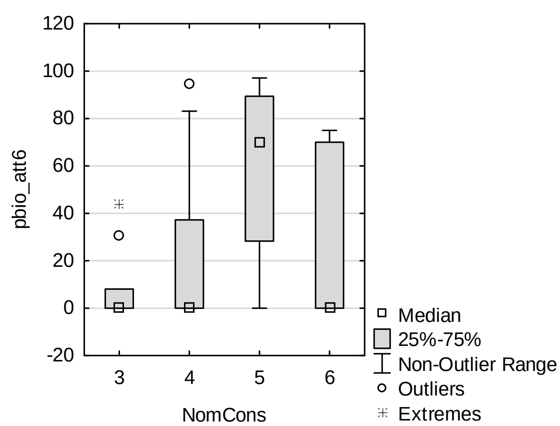
6
NomCons
Median
25%-75%
Non-Outlier Range


pbio_att6
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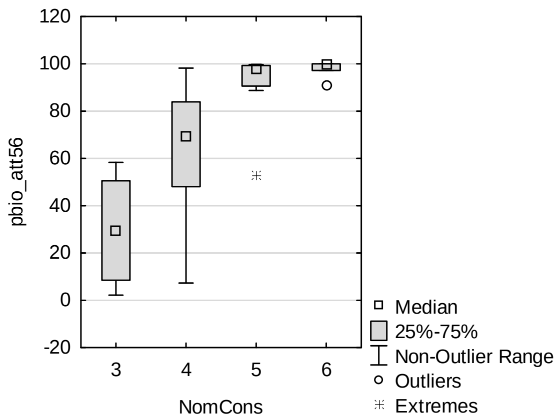
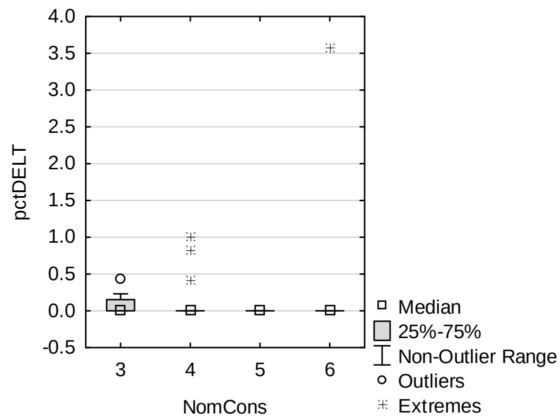
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att56
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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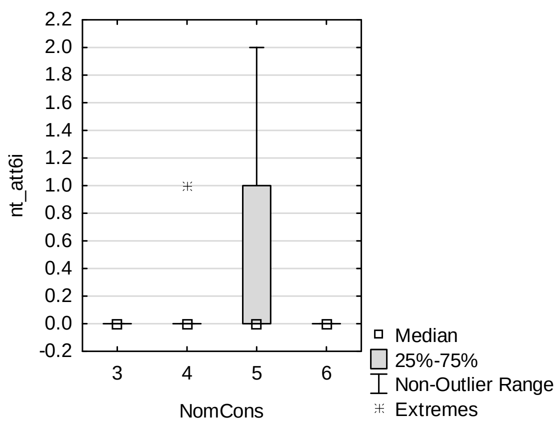
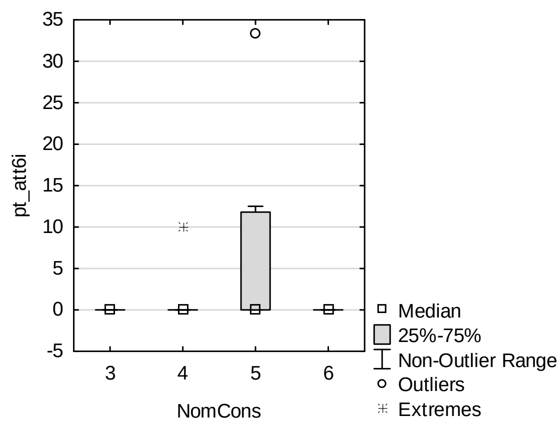
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att6i
NomCons
Median
25%-75%
Non-Outlier Range
Extremes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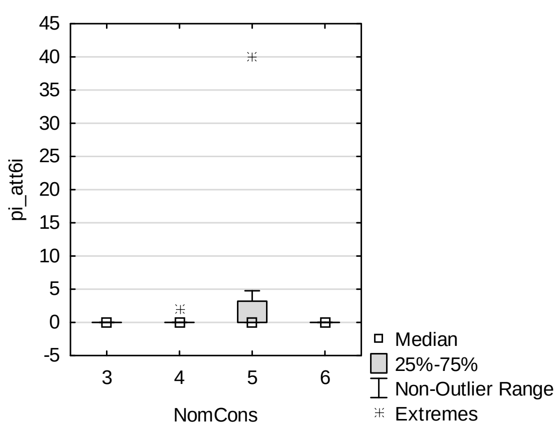
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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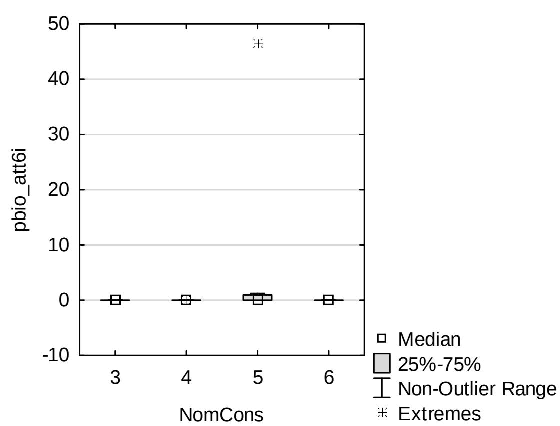
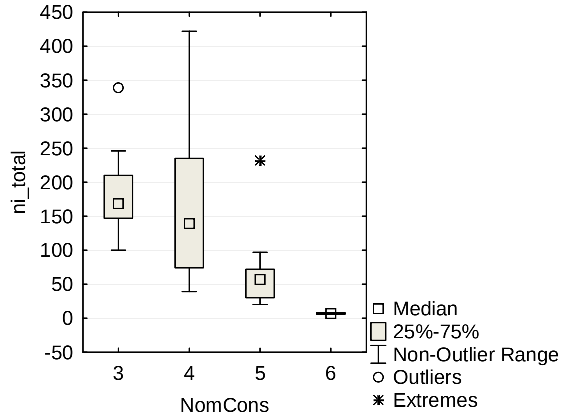
NomCons
Median
25%-75%
Non-Outlier Range
Extremes


pbio_att6i
NomCons
Median
25%-75%
Non-Outlier Range
Extremes

Southern Michigan/Northern Indiana Drift Plains


ni_total
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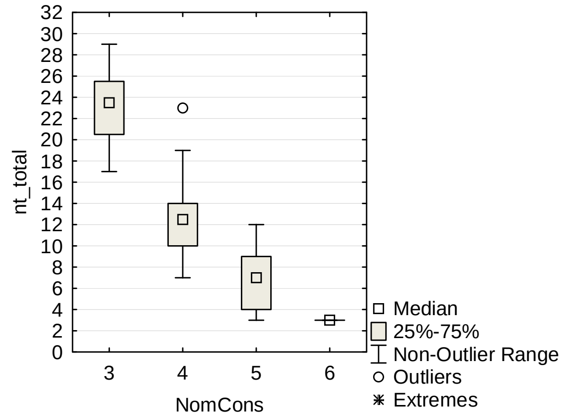
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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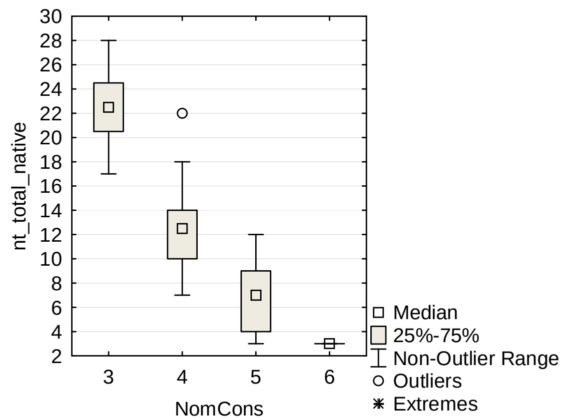
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_total_native
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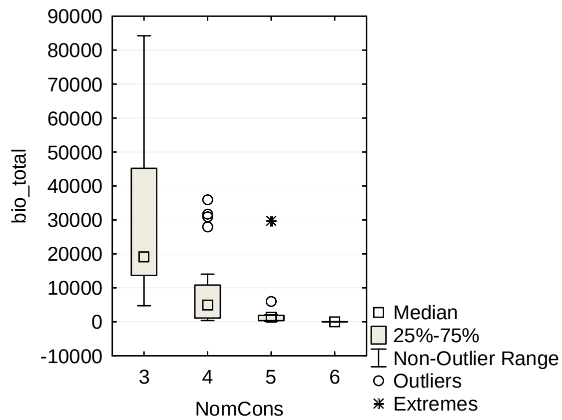
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


bio_total
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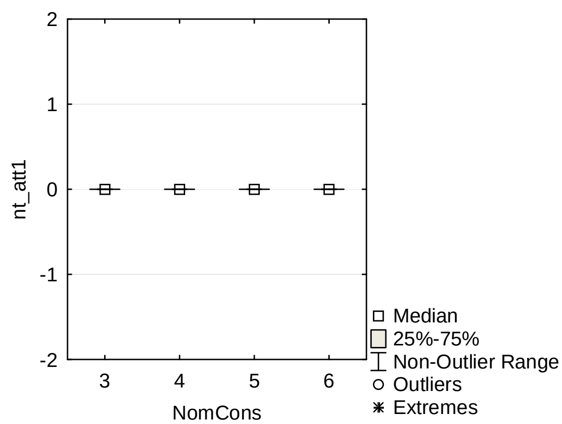
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att1
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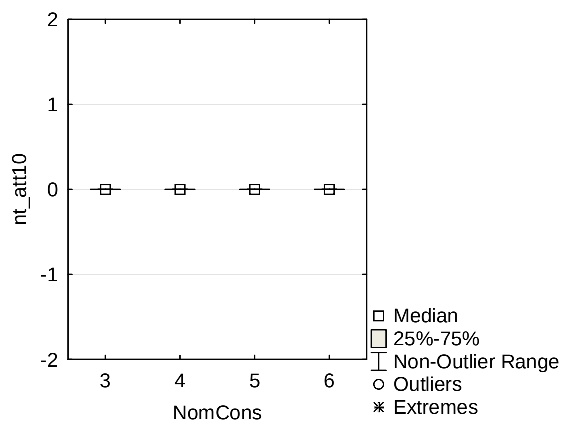
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att10
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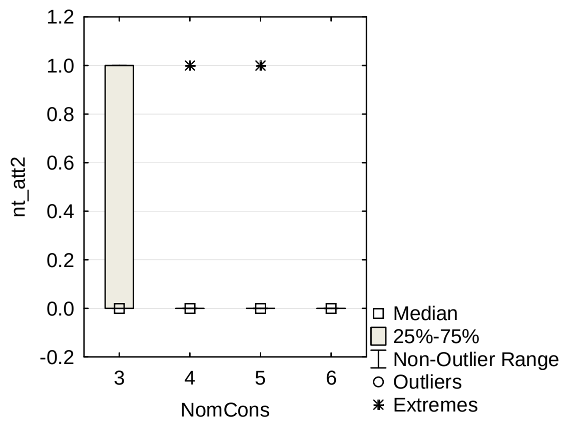
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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5
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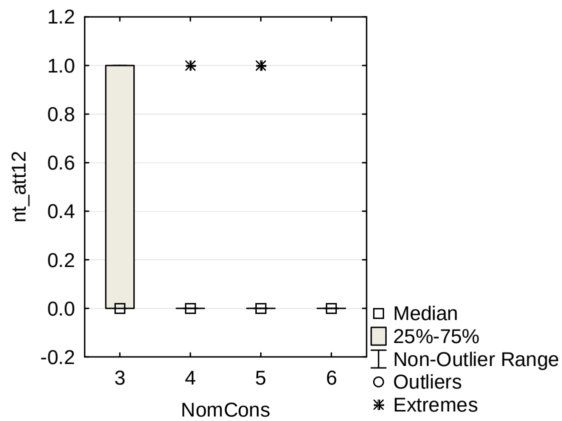
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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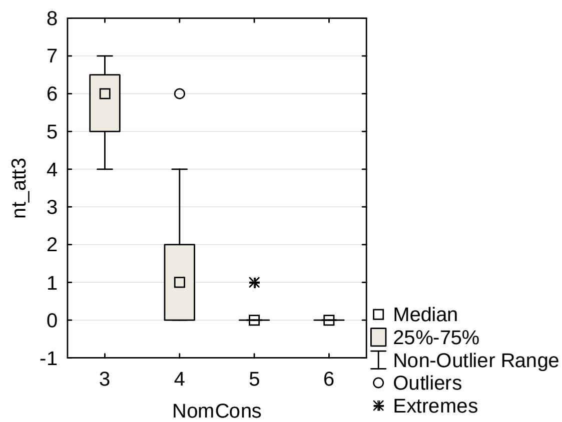
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att3
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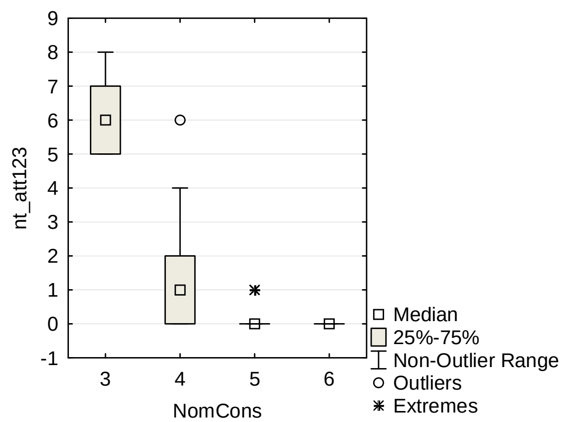
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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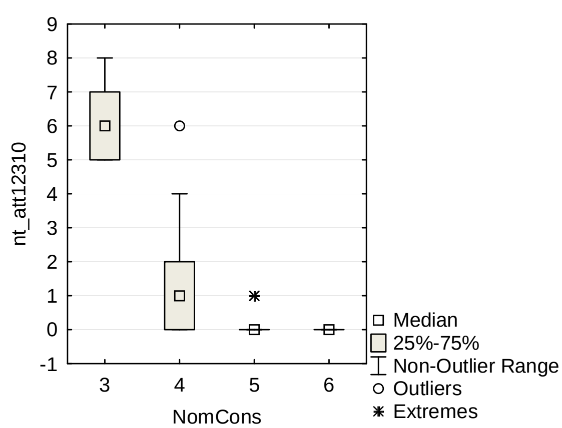
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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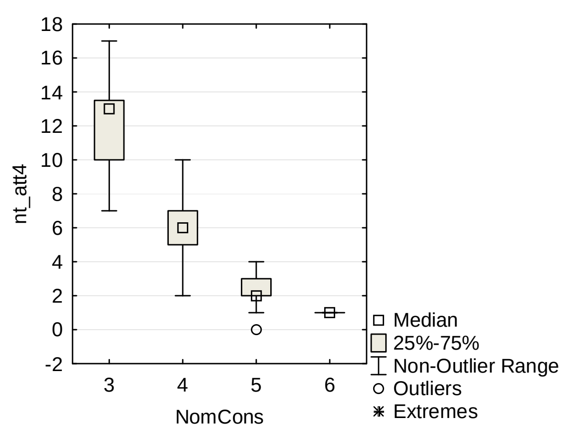
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att4
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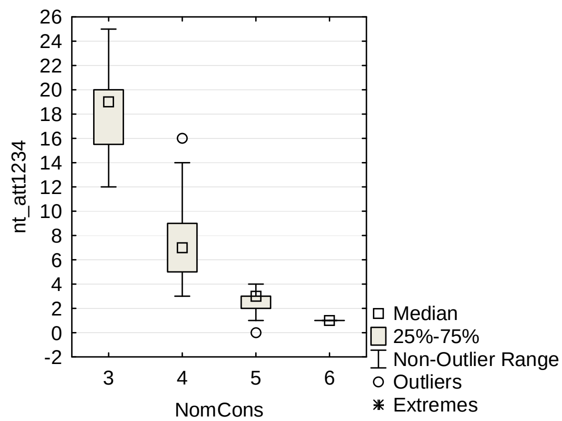
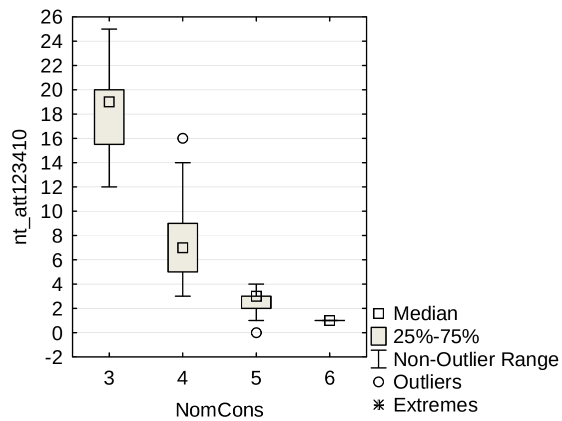
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att1234
26 24 22 20 18 16 14 12 10 8 6 4 2 0 -2
3 4 5 6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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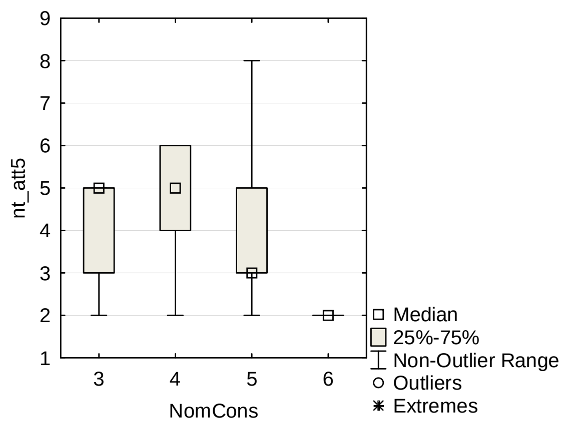
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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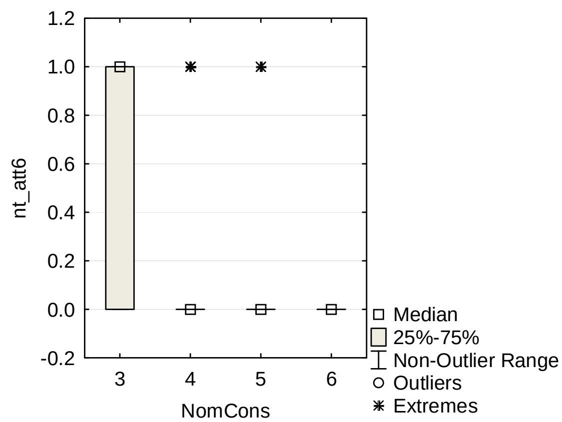
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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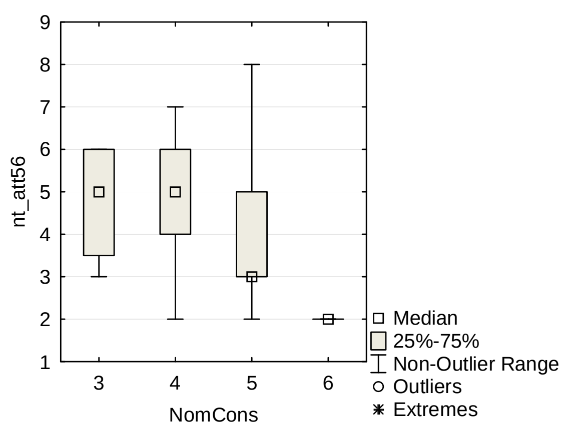
3 4 5 6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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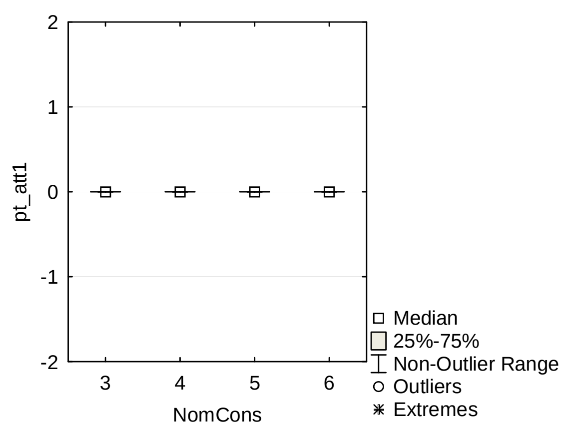
3 4 5 6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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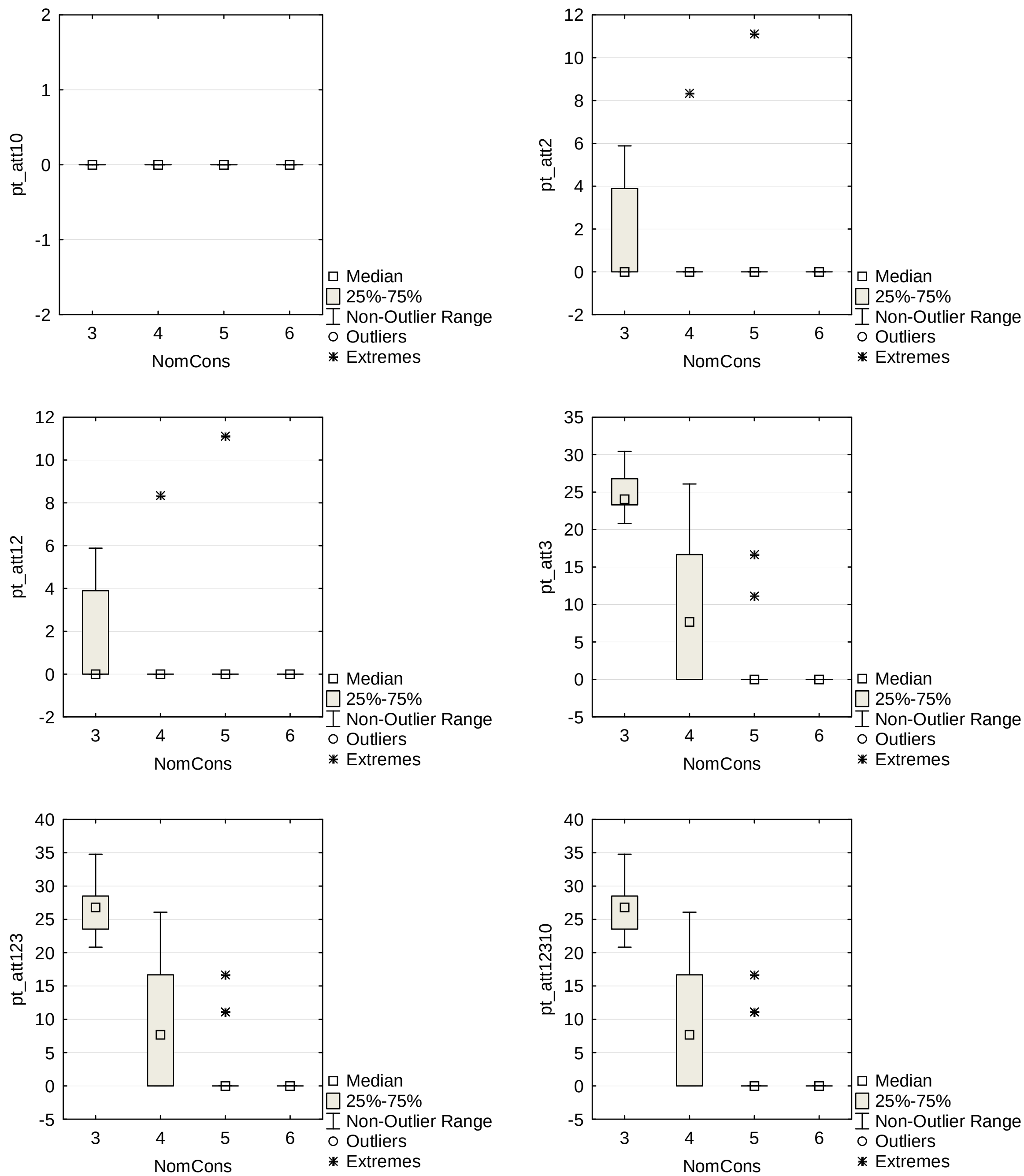
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



pt_att10
pt_att2
pt_att12
pt_att3
pt_att123
pt_att12310
NomCons
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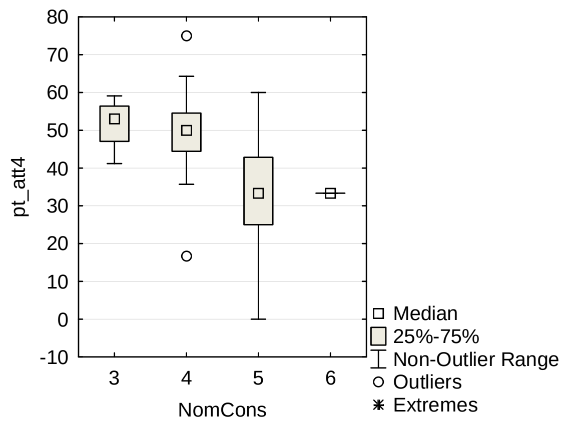
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att4
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NomCons
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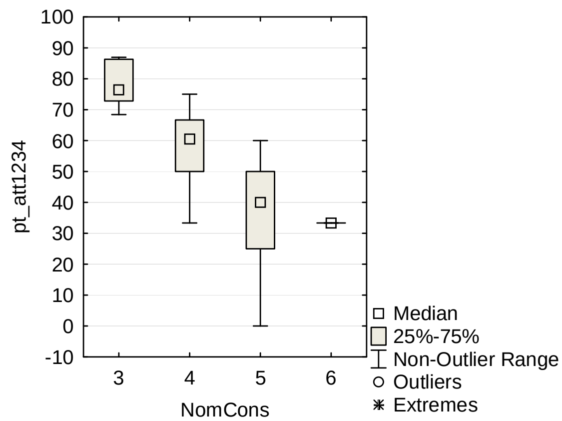
Non-Outlier Range
Outliers
Extremes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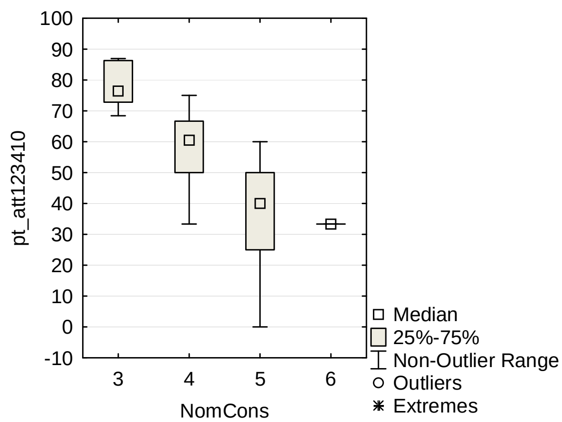
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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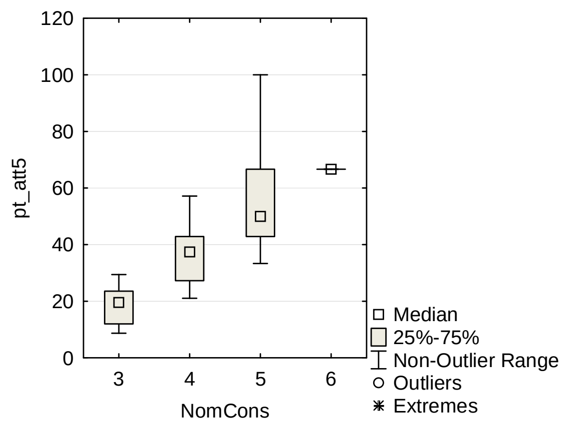
Non-Outlier Range
Outliers
Extremes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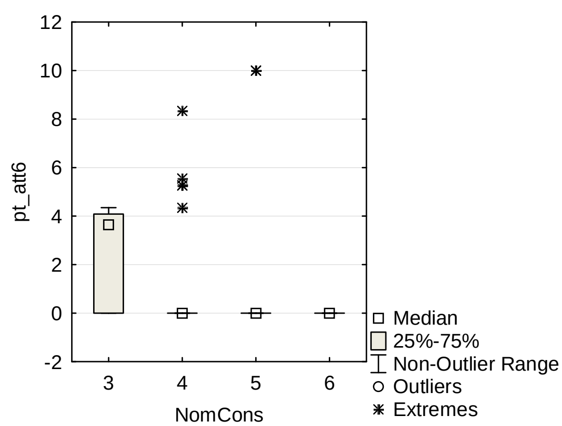
Non-Outlier Range
Outliers
Extremes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10
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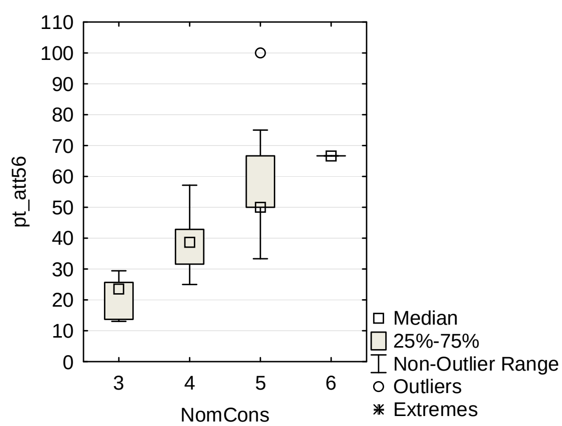
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att56
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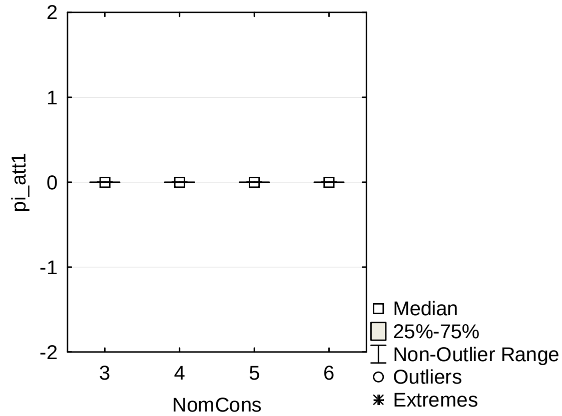
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att1
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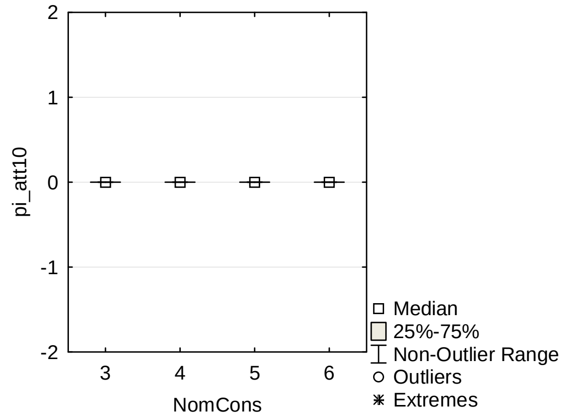
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att10
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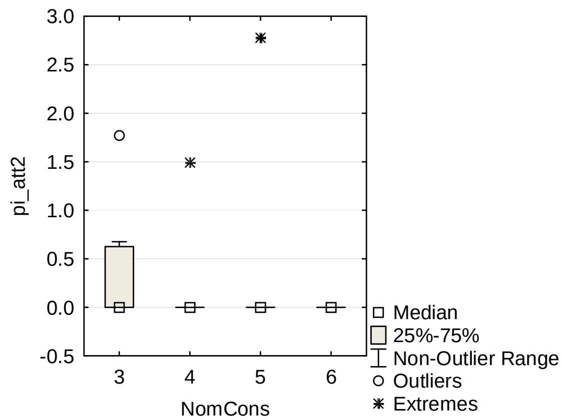
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att2
3.0
2.5
2.0
1.5
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0.0
-0.5
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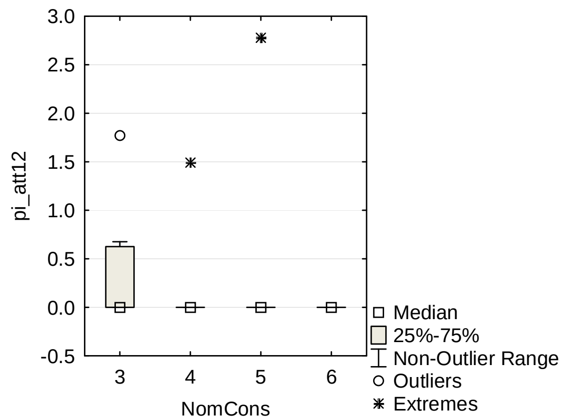
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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2.0
1.5
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0.5
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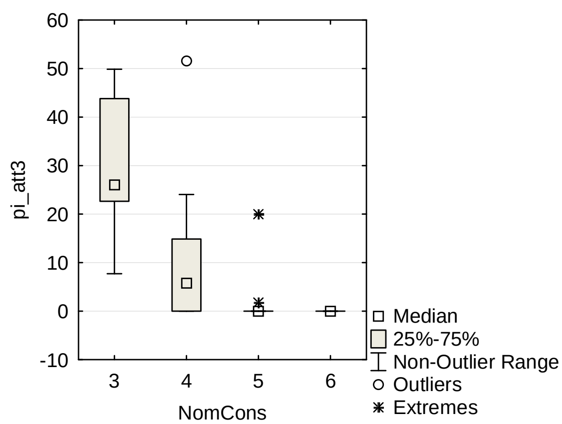
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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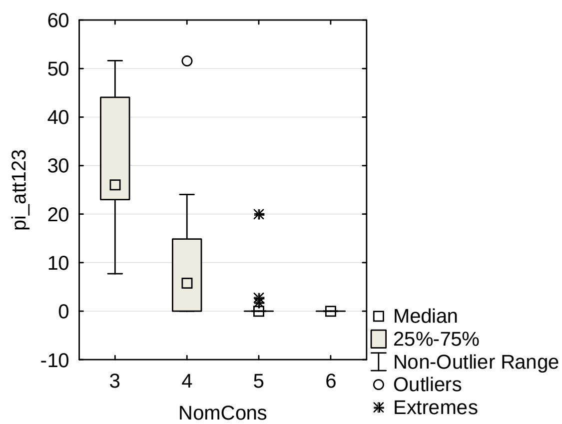
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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-10
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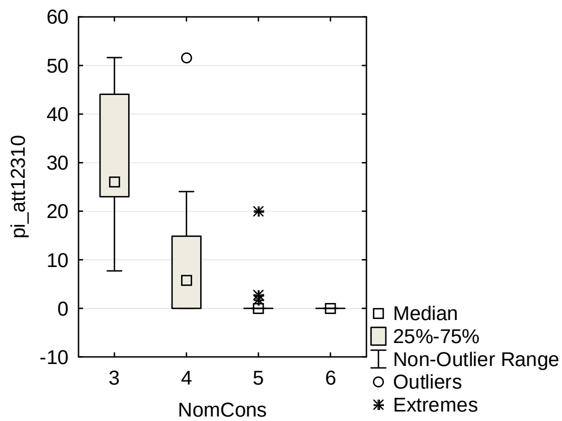
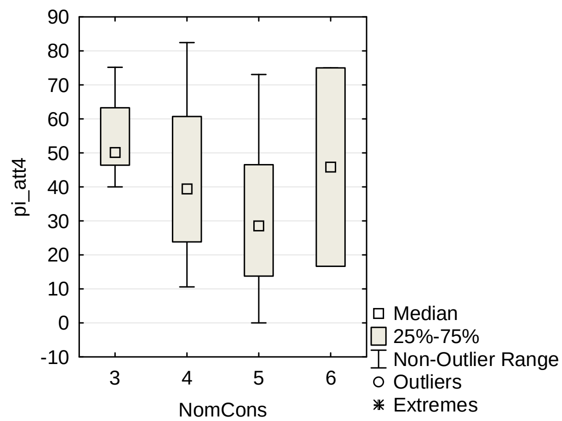
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att12310
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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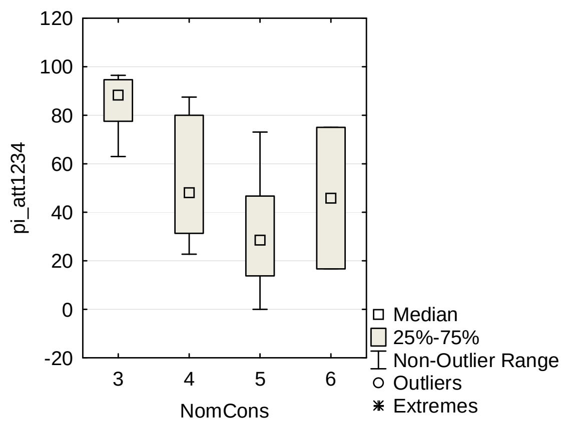
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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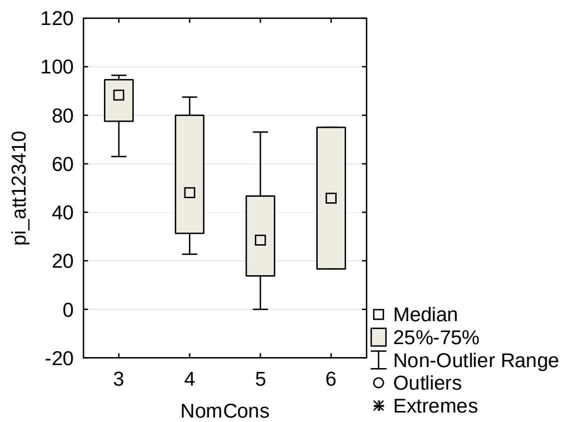
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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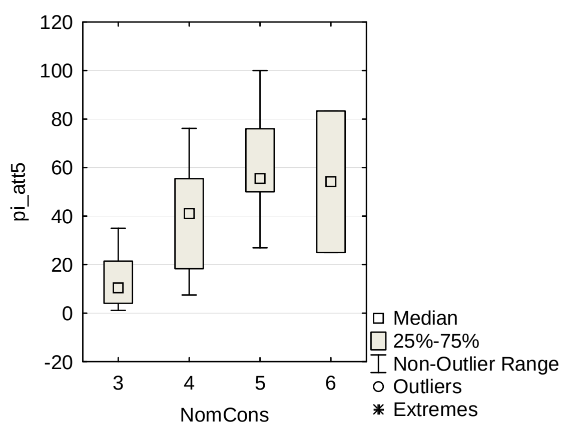
25%-75%
Non-Outlier Range
Outliers
Extremes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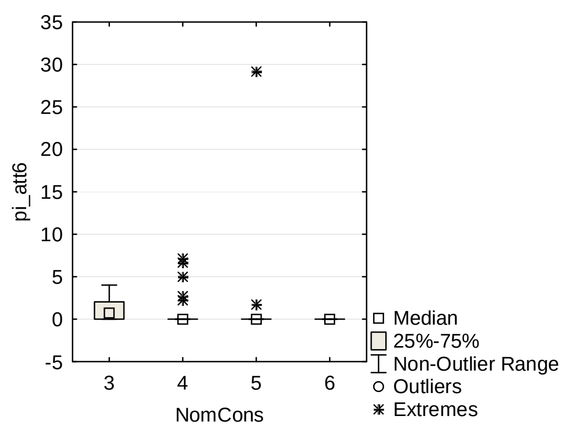
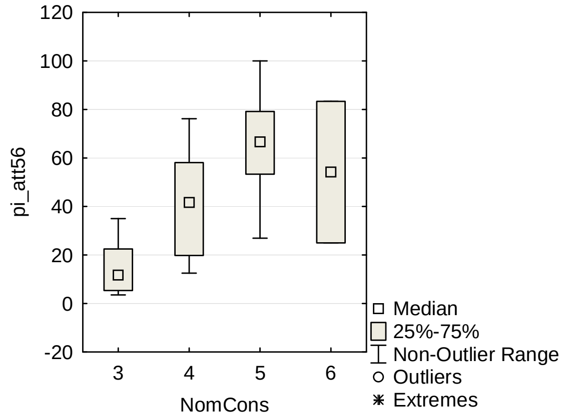
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att56
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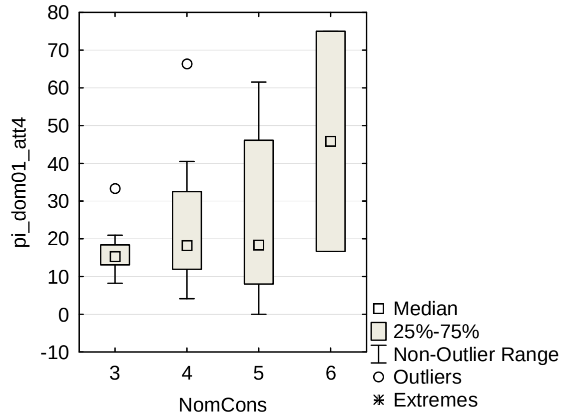
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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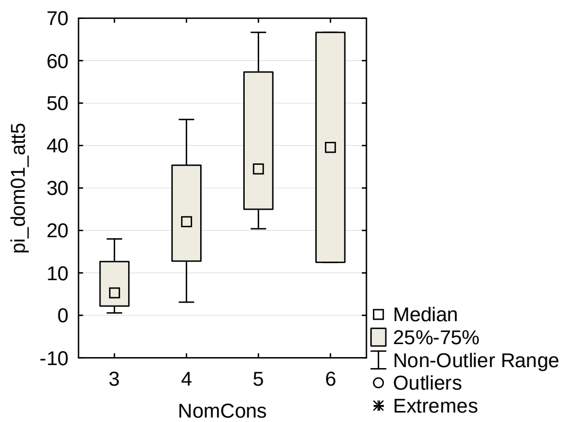
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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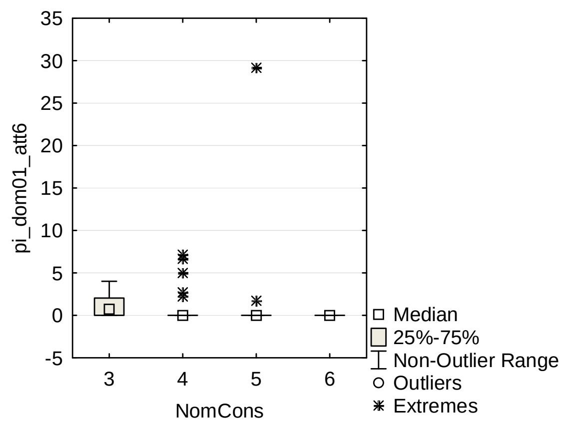
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att6
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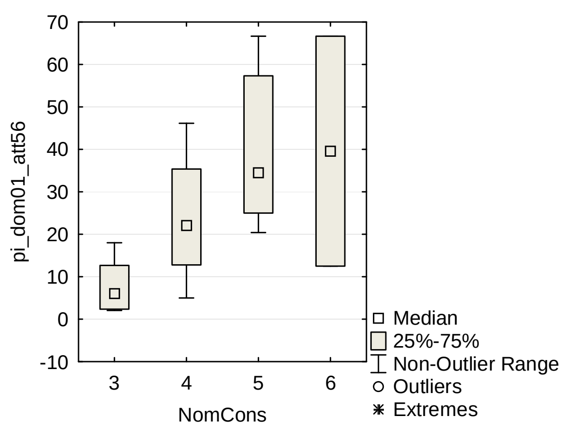
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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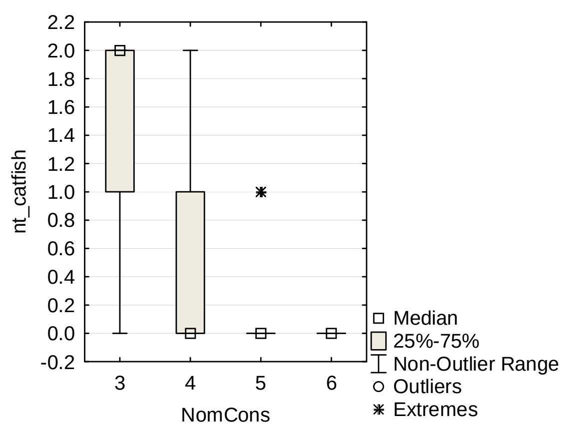
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_catfish
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1.0
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0.6
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4
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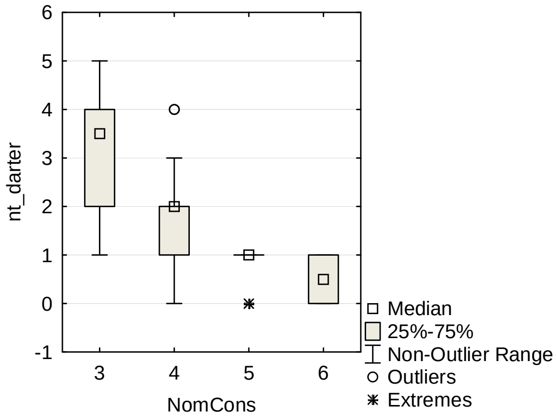
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_darter
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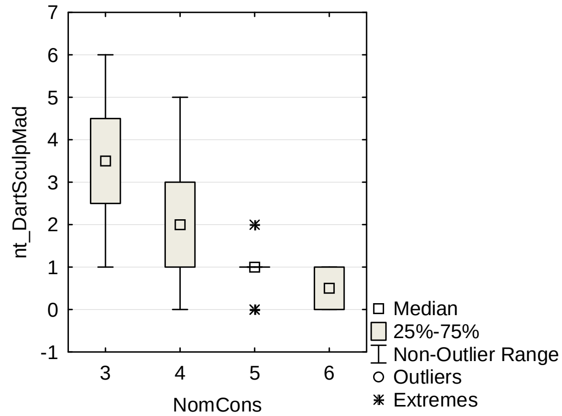
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_DartSculpMad
7
6
5
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3
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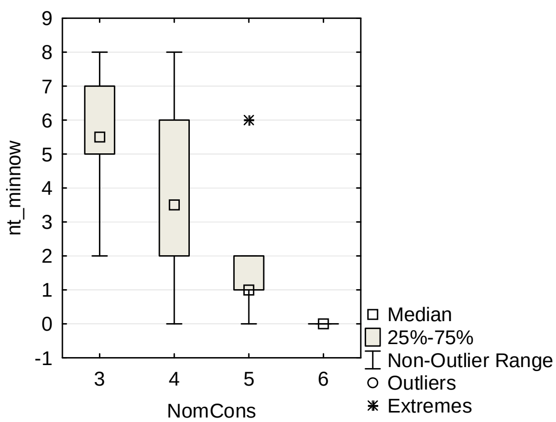
0
-1
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_minnow
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5
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-1
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4
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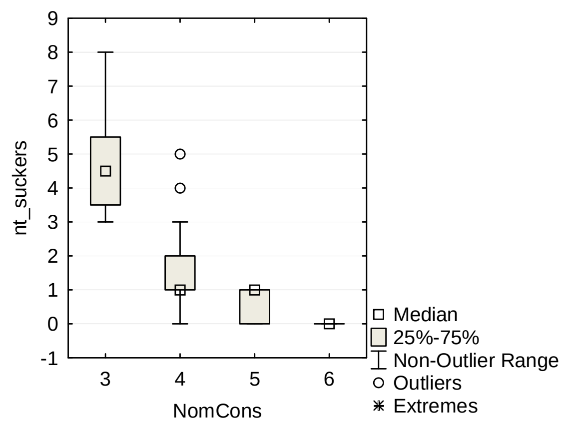
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_suckers
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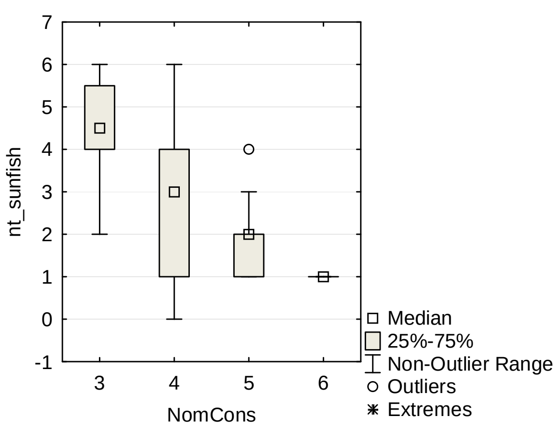
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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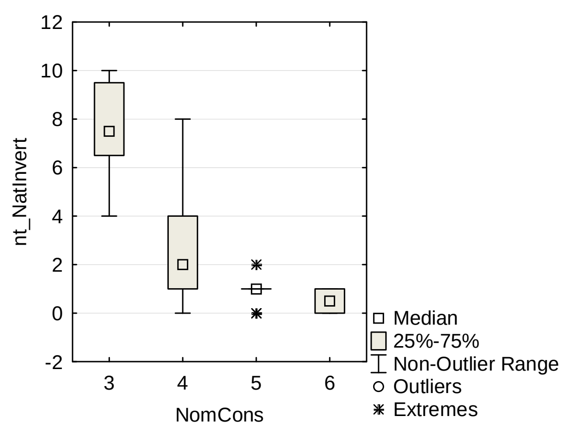
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_NatInvert
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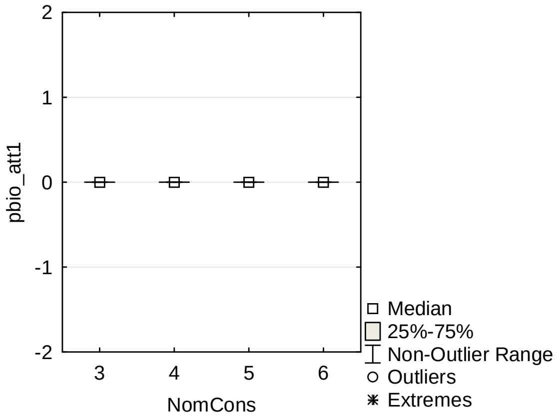
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att1
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-2
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4
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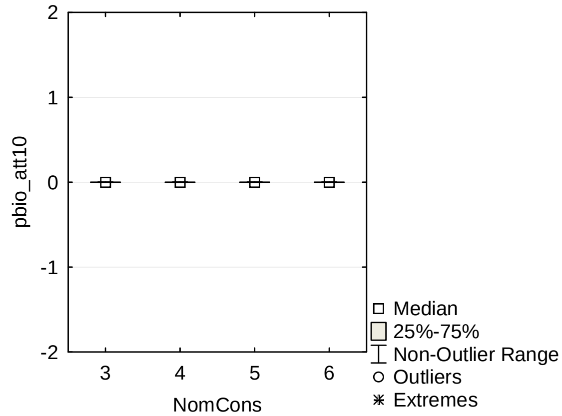
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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6
NomCons
Median
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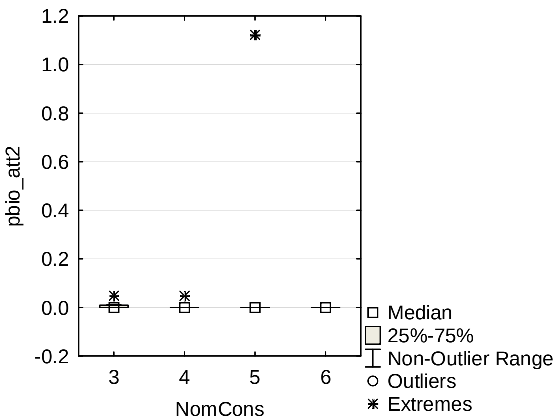
Non-Outlier Range
Outliers
Extremes


pbio_att2
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-0.2
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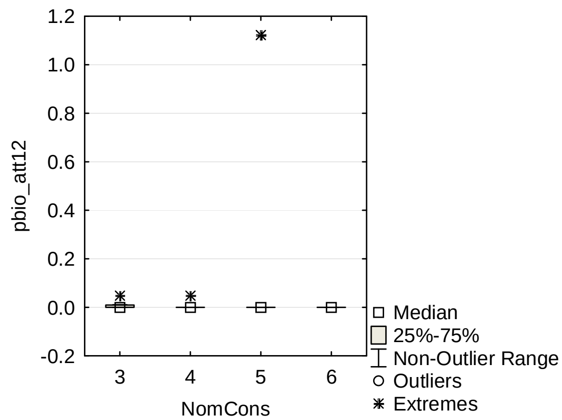
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att12
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4
5
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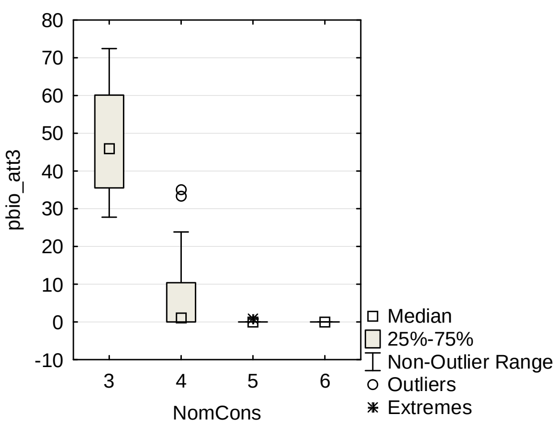
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att3
80
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60
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4
5
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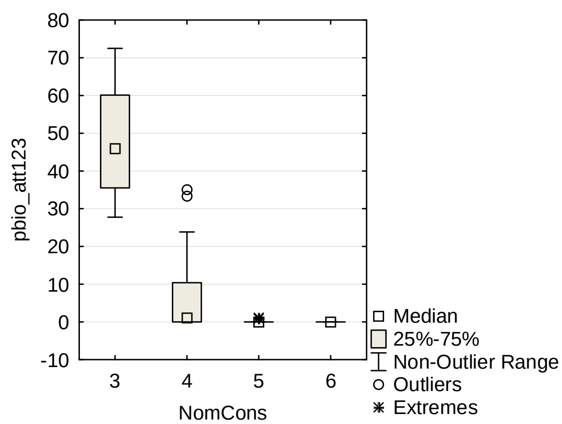
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att123
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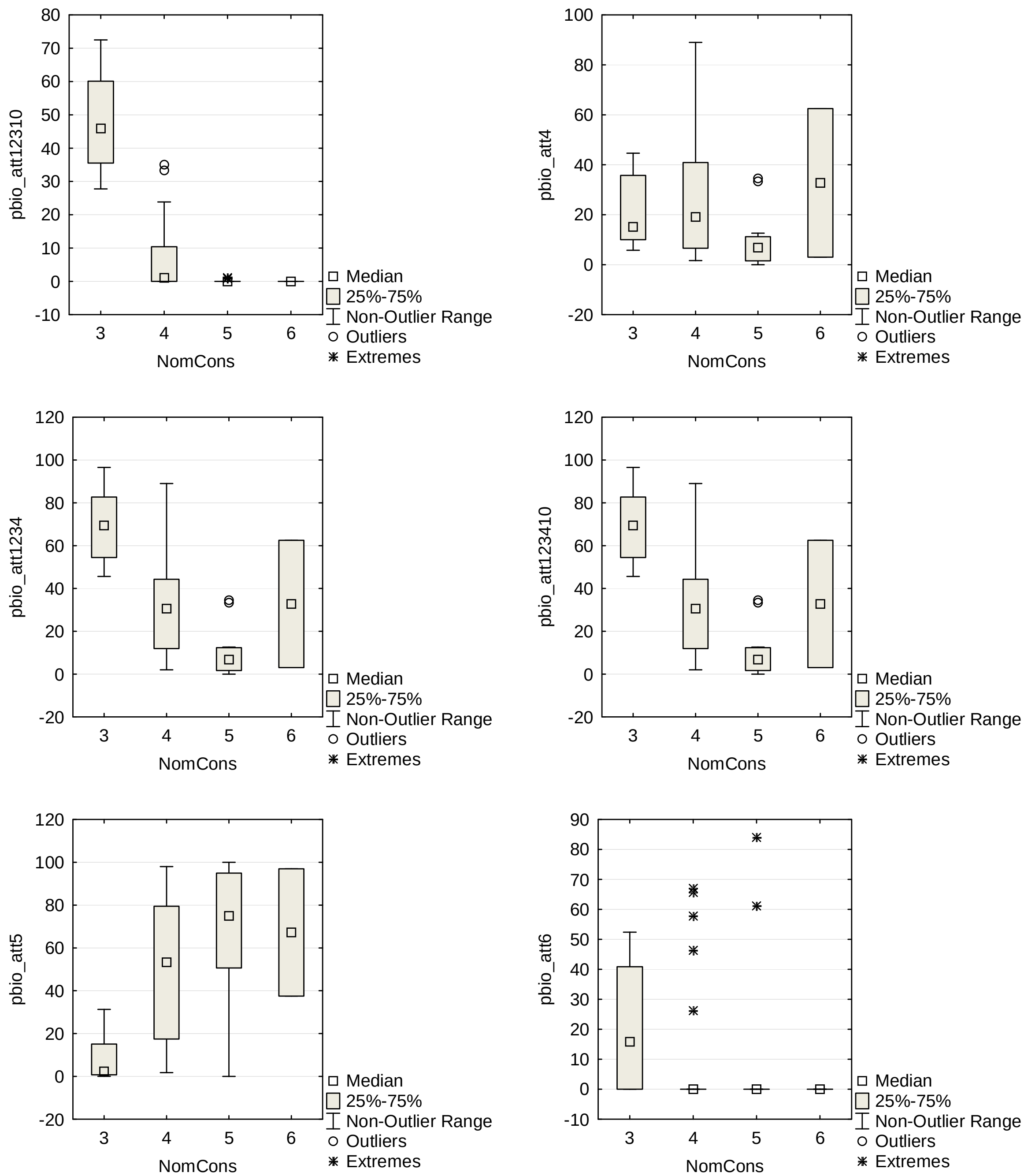
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att12310
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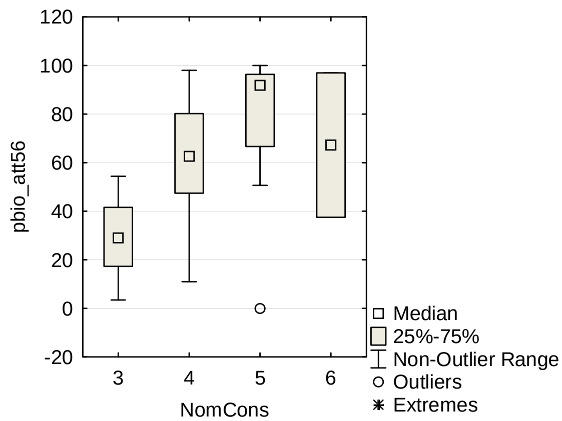
pbio_att1234
pbio_att123410
pbio_att5
pbio_att6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
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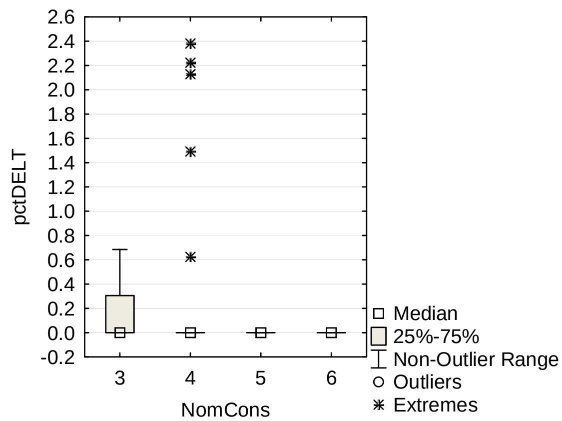
Non-Outlier Range
Outliers
Extremes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1.6
1.4
1.2
1.0
0.8
0.6
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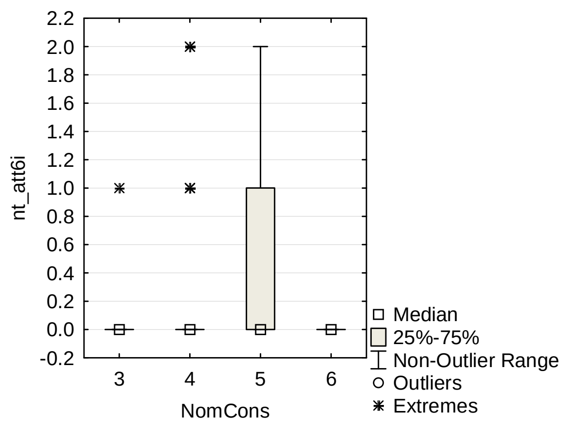
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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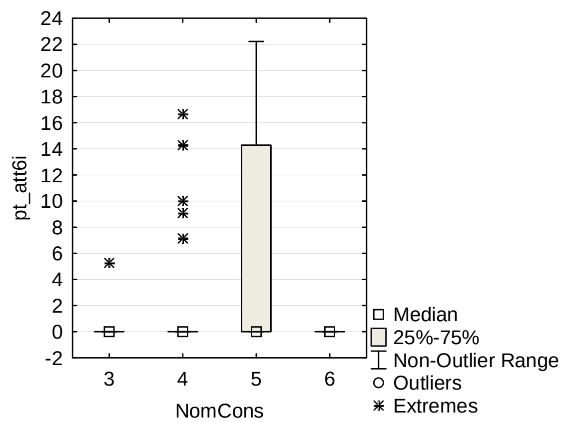
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
3
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att6i
24
22
20
18
16
14
12
10
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0
-2
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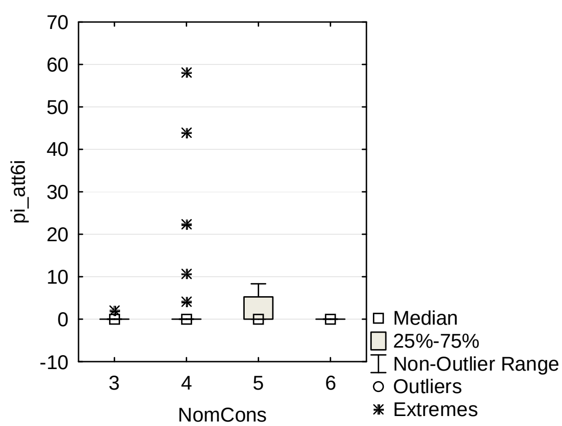
4
5
6
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att6i
70
60
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-10
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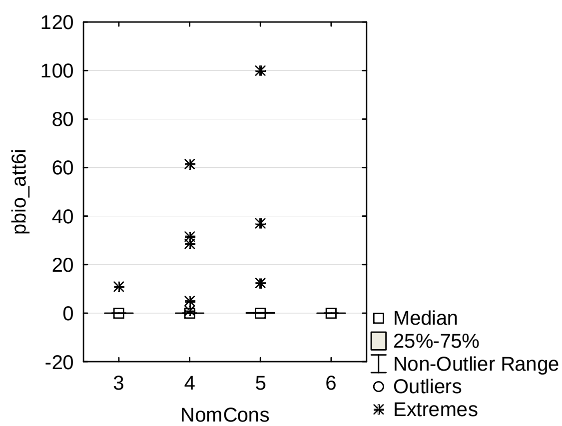
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att6i
120
100
80
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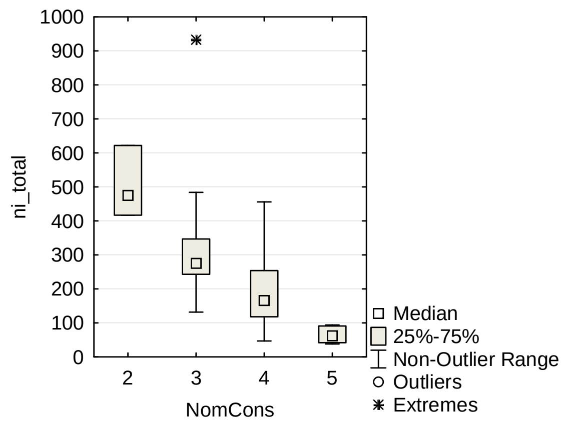
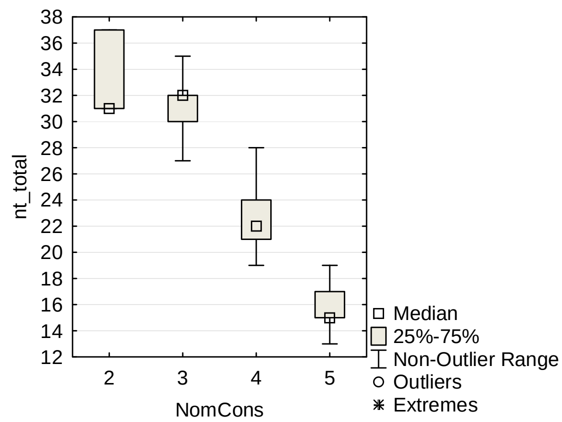
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Large Rivers


ni_total
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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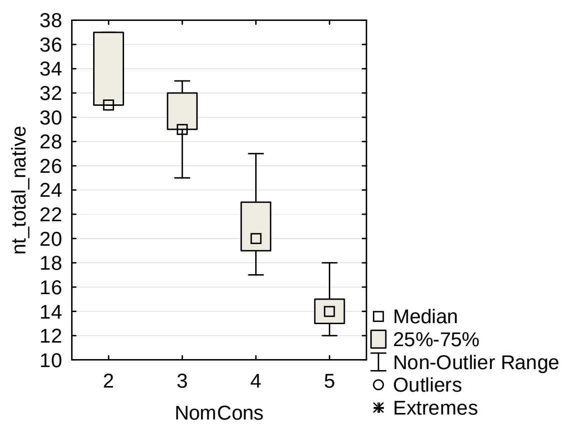
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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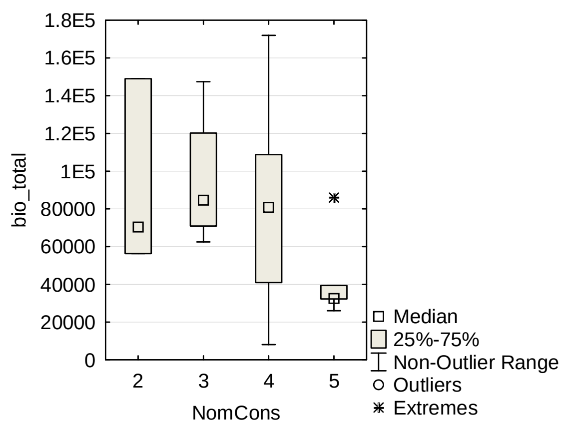
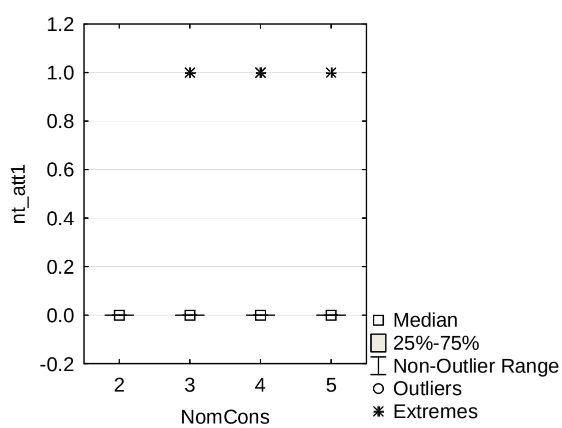
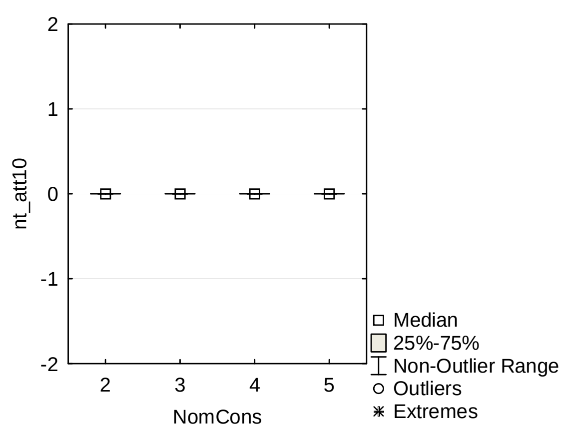
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


bio_total
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att1
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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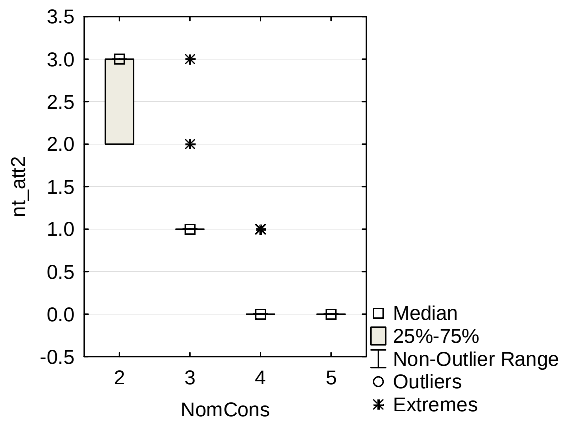
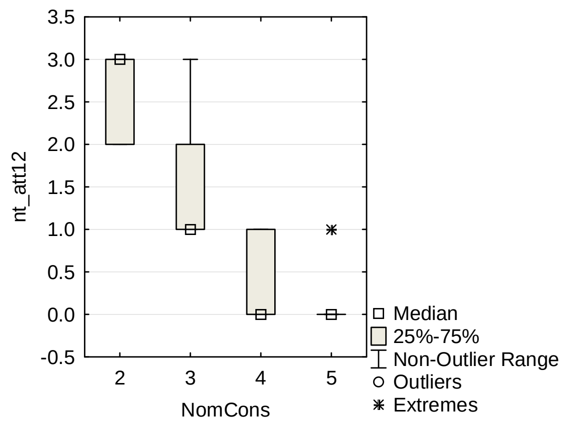
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att2
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att12
3.5
3.0
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2.0
1.5
1.0
0.5
0.0
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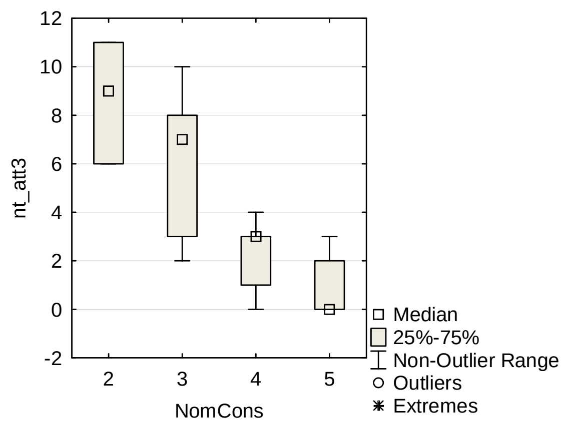
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att3
12
10
8
6
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4
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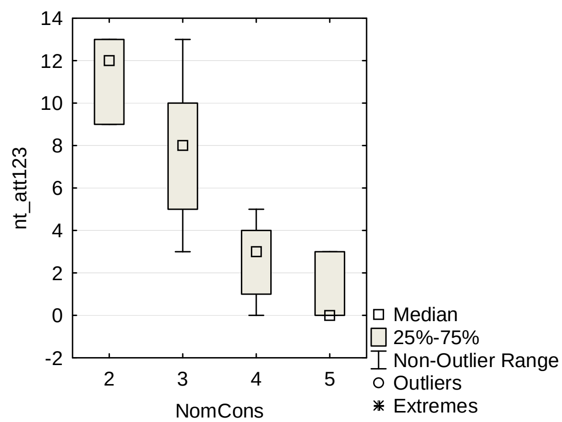
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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12
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4
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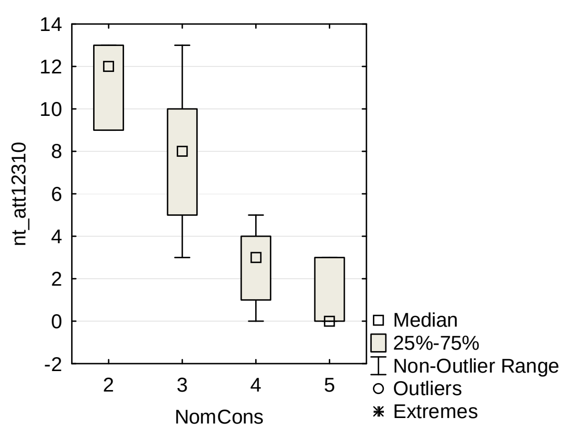
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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10
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2
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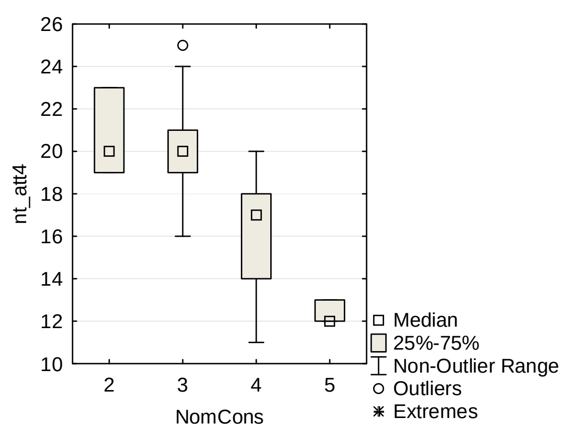
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att4
26
24
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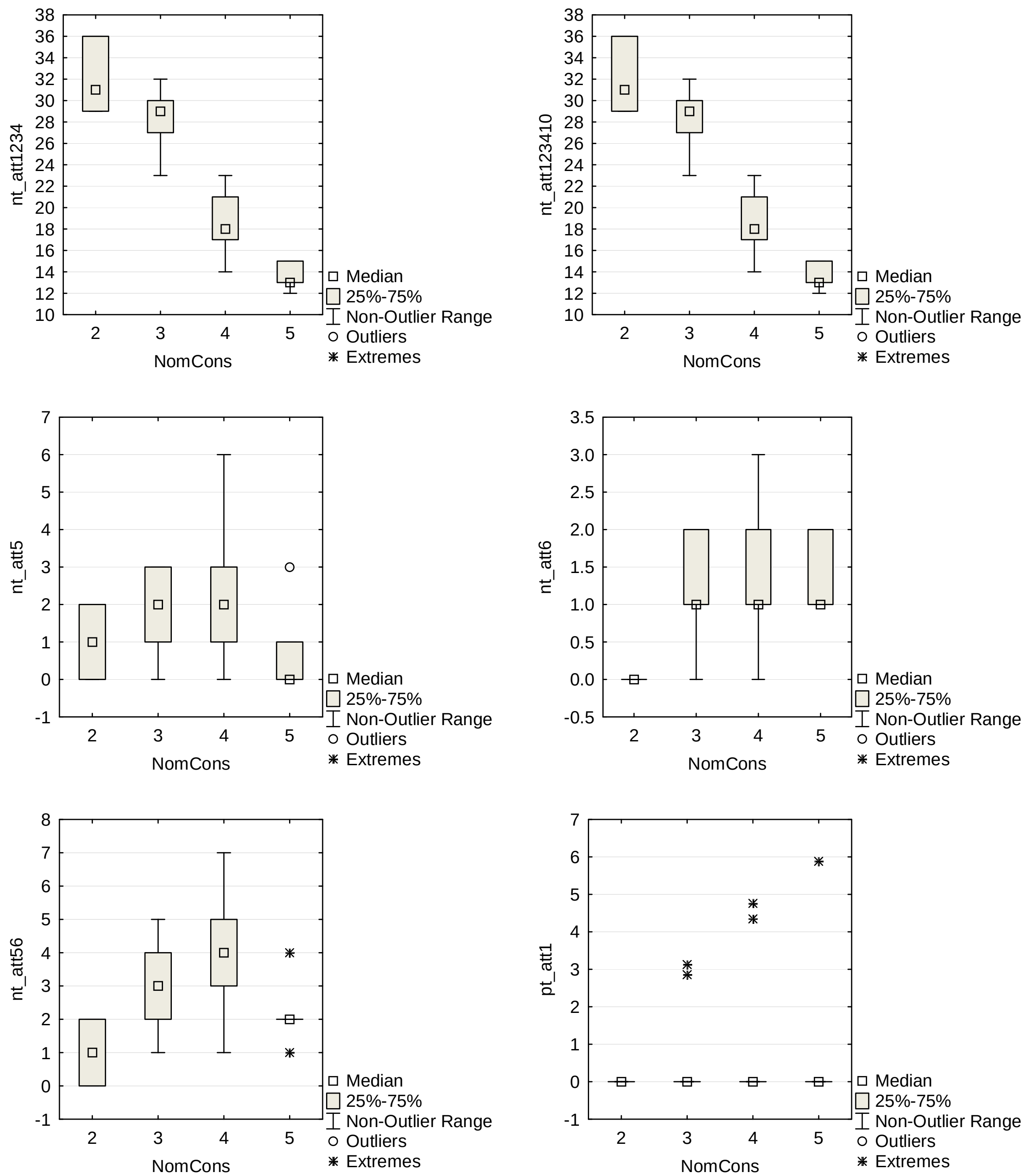
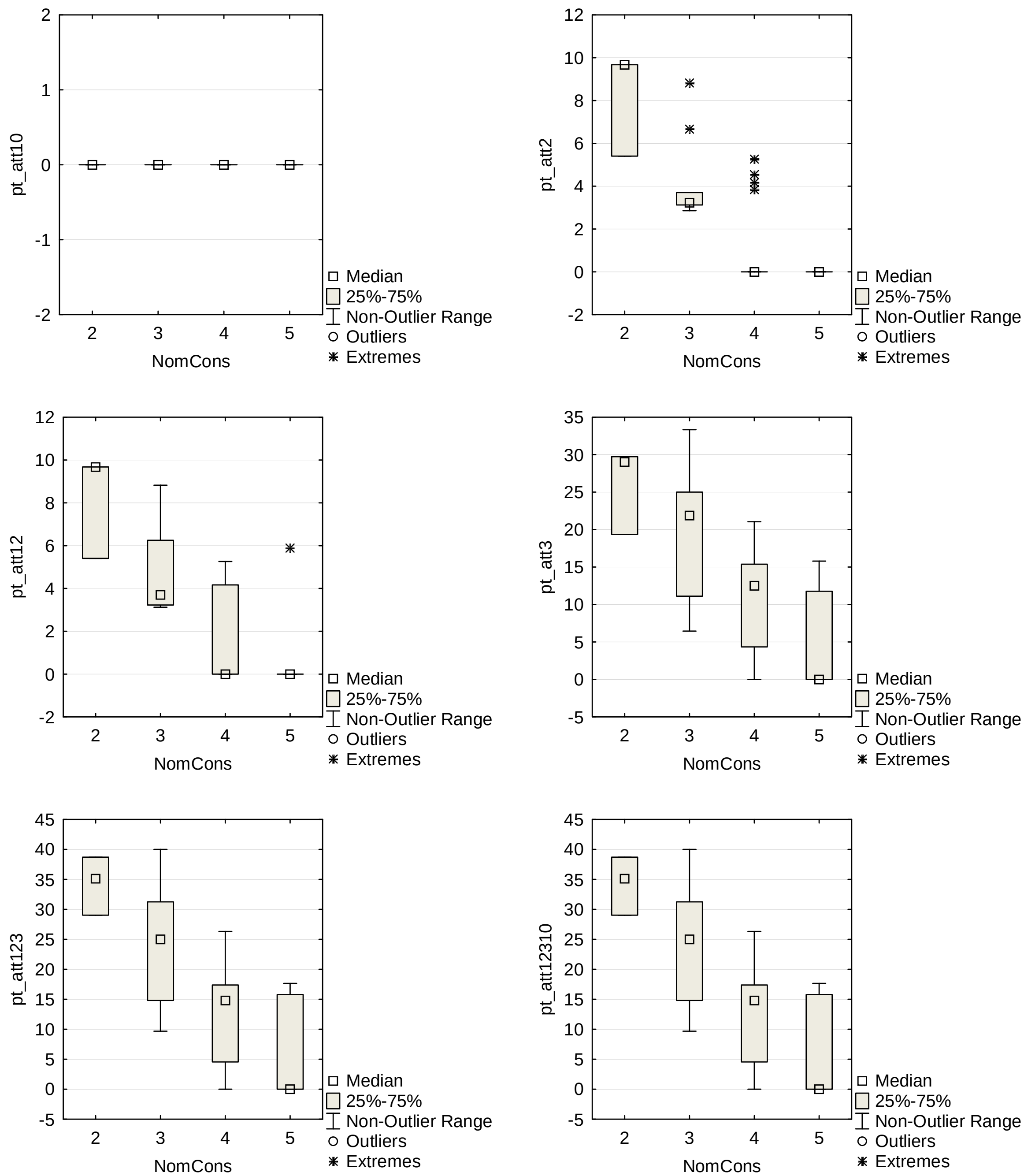
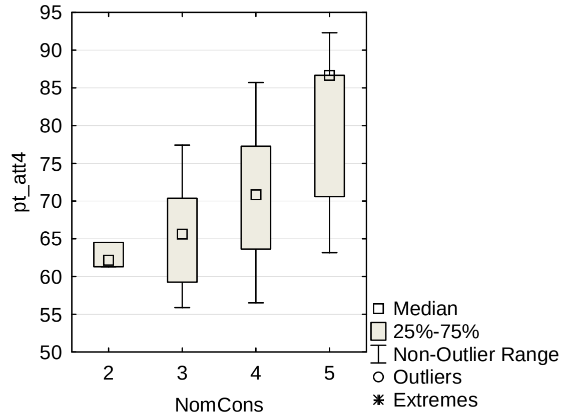
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att1234
nt_att123410
nt_att5
nt_att6
nt_att56
pt_att1
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



pt_att10
pt_att2
pt_att12
pt_att3
pt_att123
pt_att12310
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att4
95
90
85
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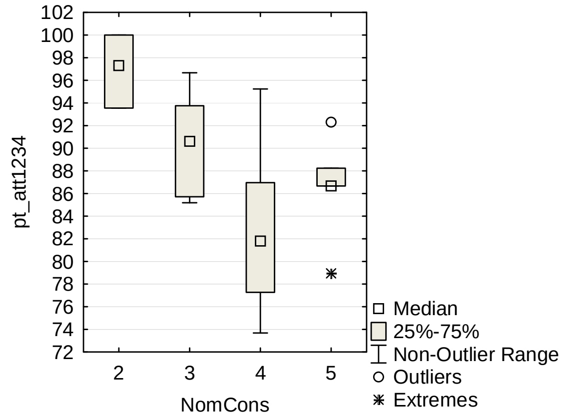
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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102
100
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NomCons
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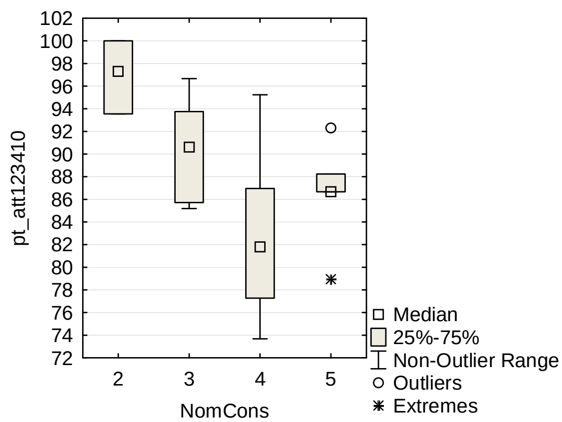
25%-75%
Non-Outlier Range
Outliers
Extremes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92
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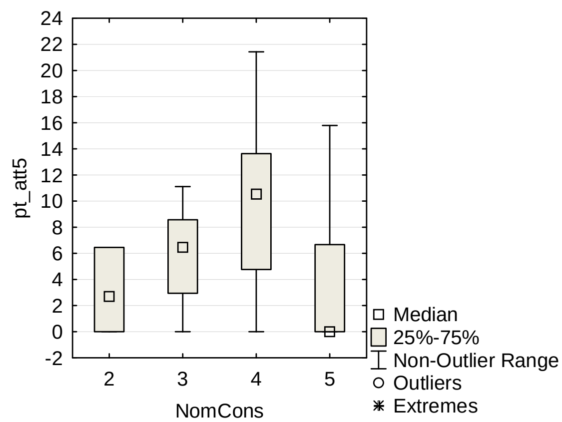
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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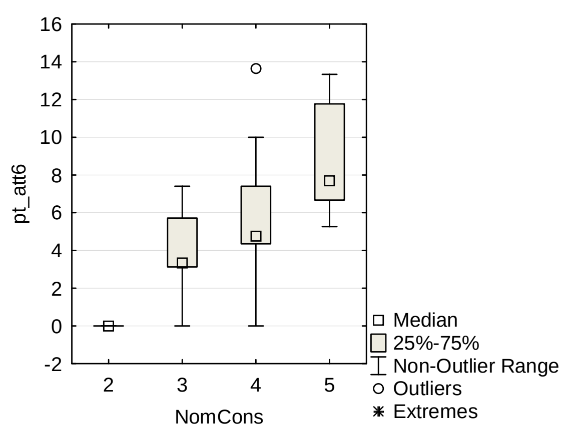
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att6
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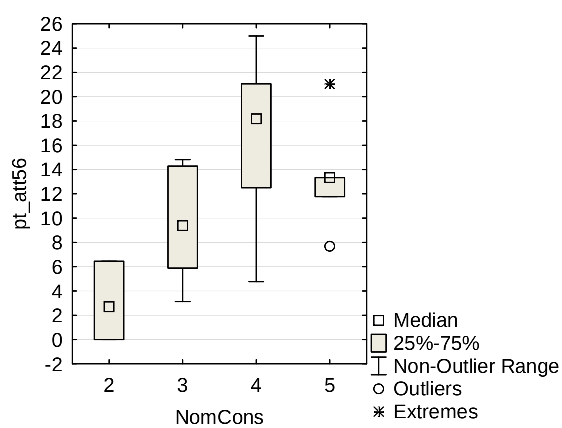
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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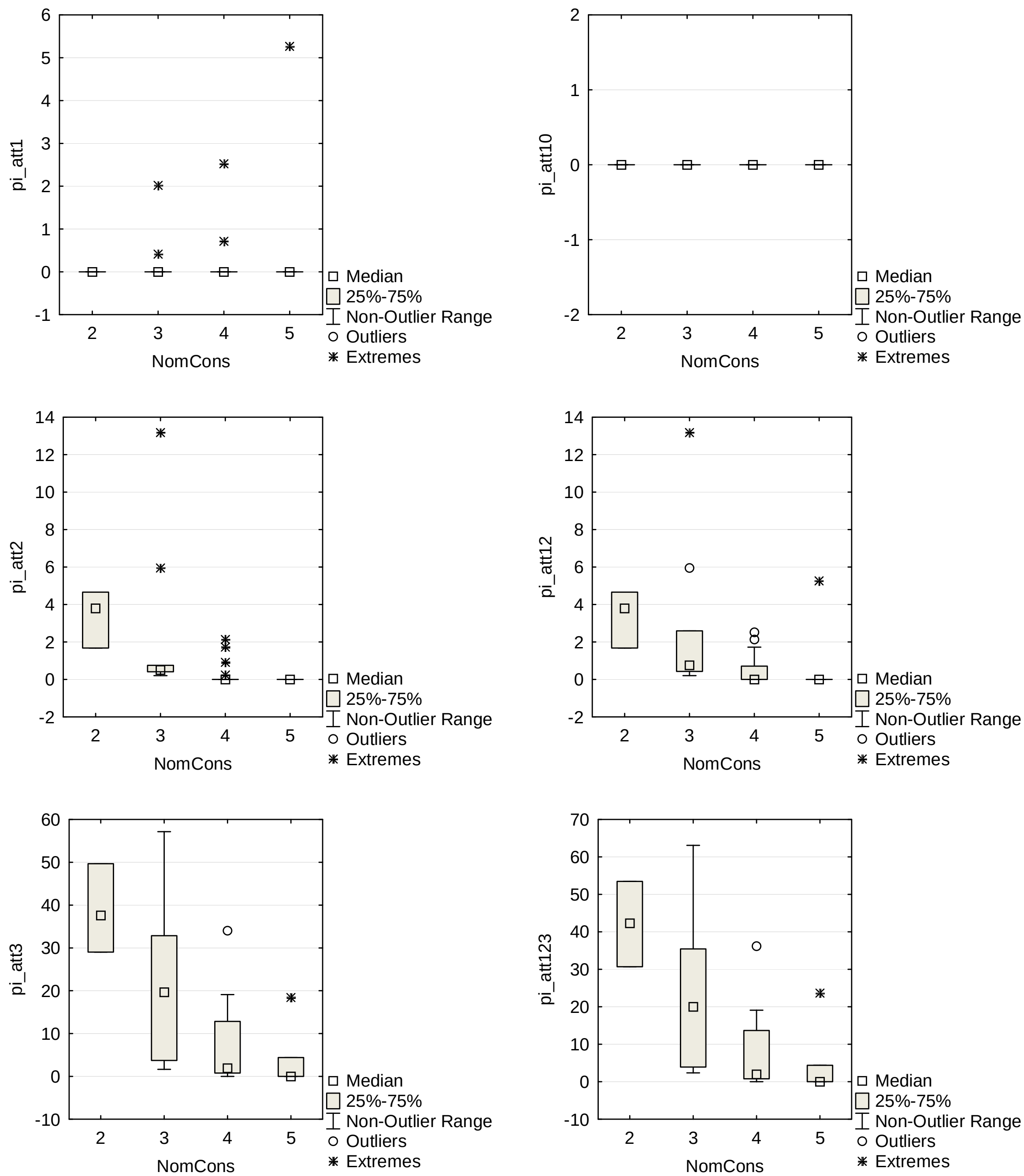
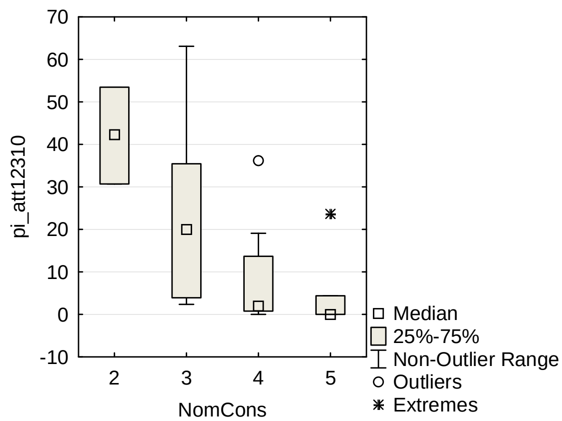
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att1
pi_att10
pi_att2
pi_att12
pi_att3
pi_att123
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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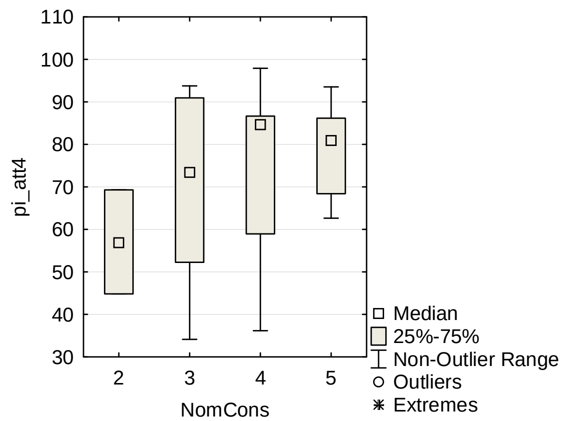
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att4
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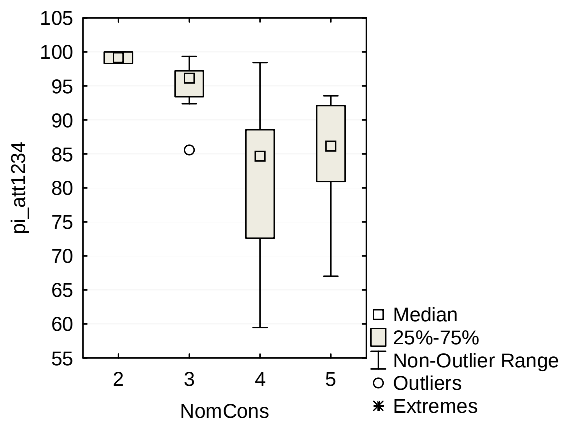
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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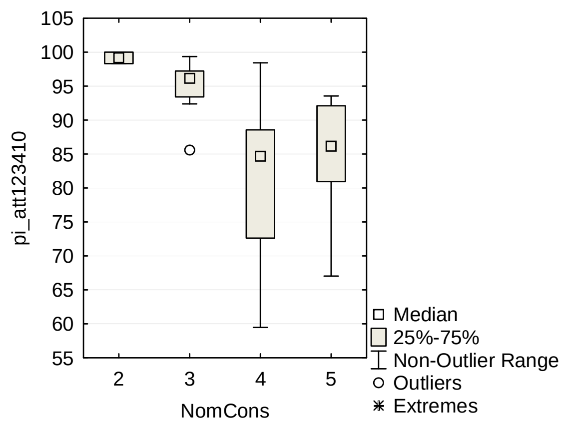
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att123410
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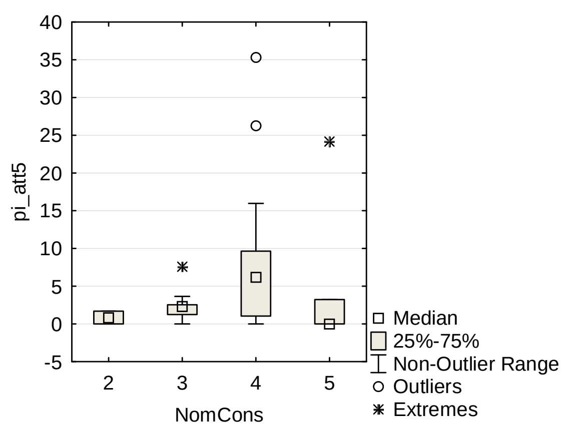
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_att5
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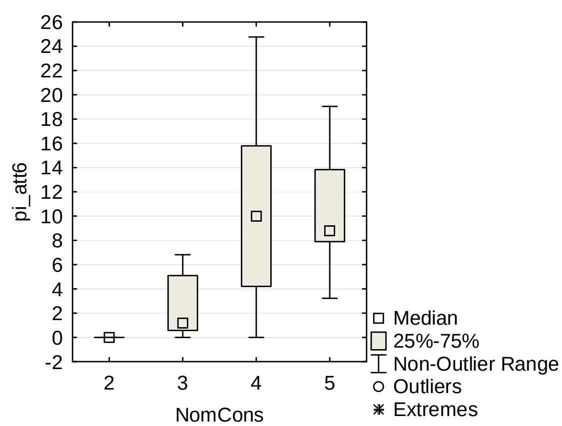
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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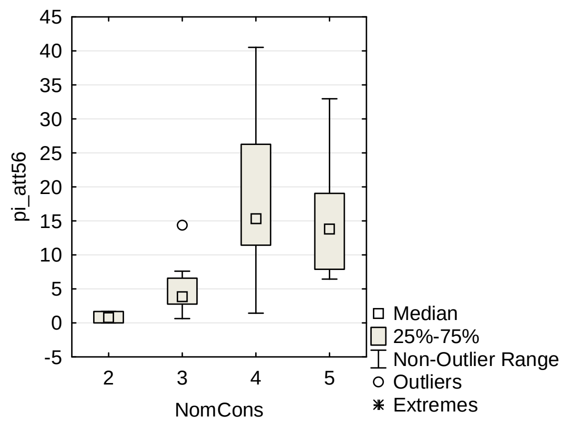
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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NomCons
Median
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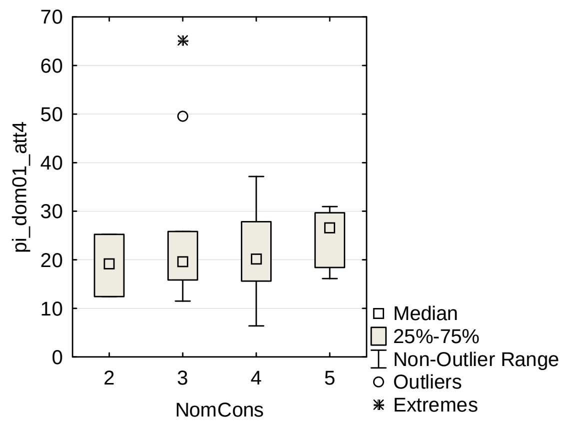
Non-Outlier Range
Outliers
Extremes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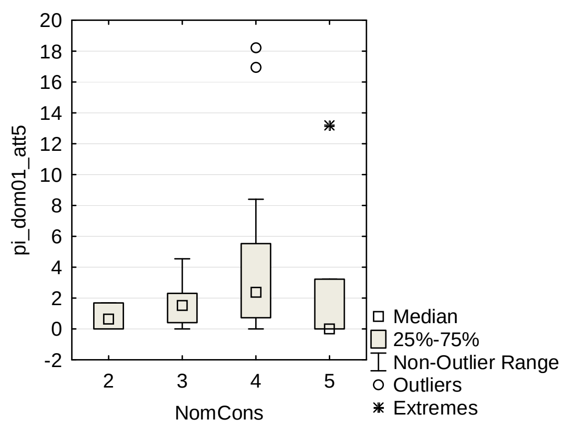
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att5
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16
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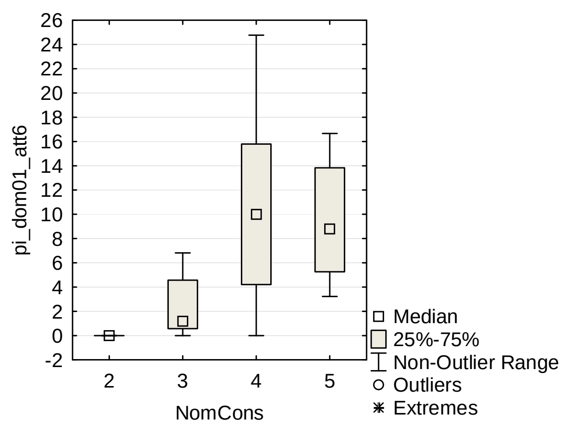
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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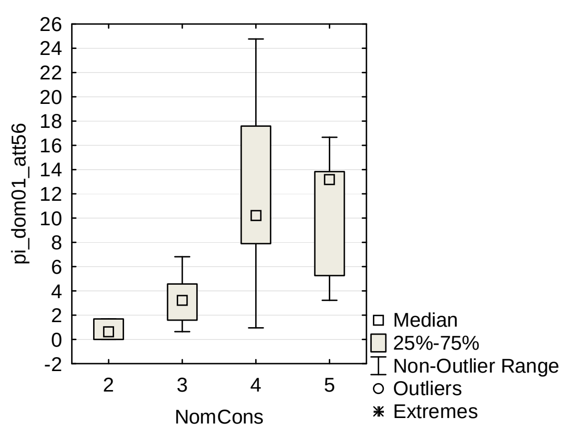
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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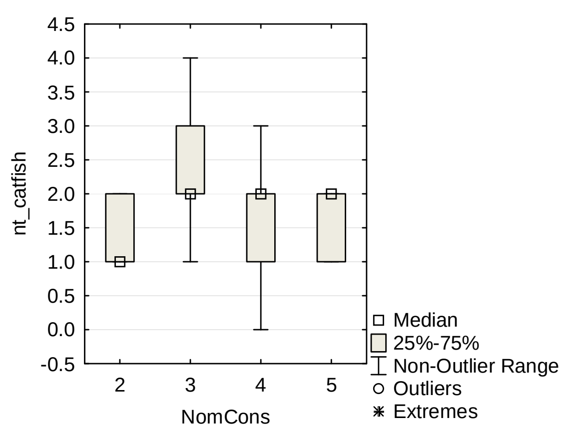
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_catfish
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4
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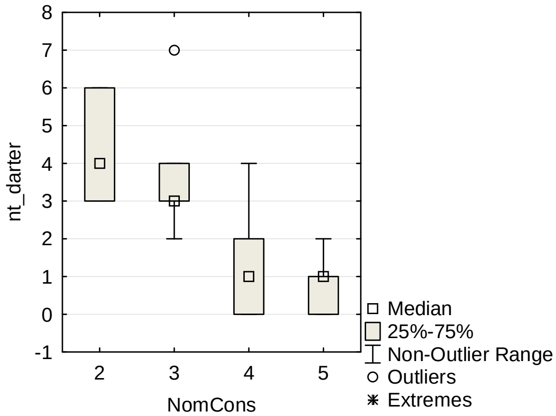
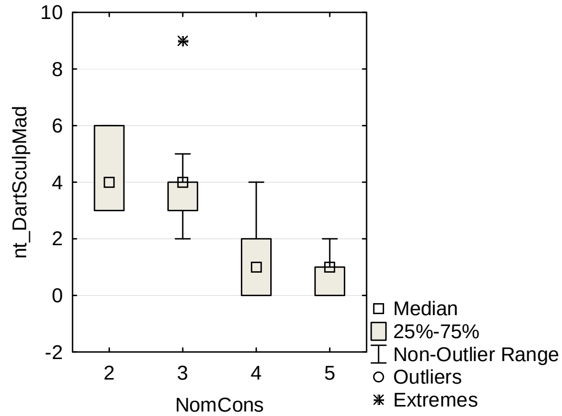
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_darter
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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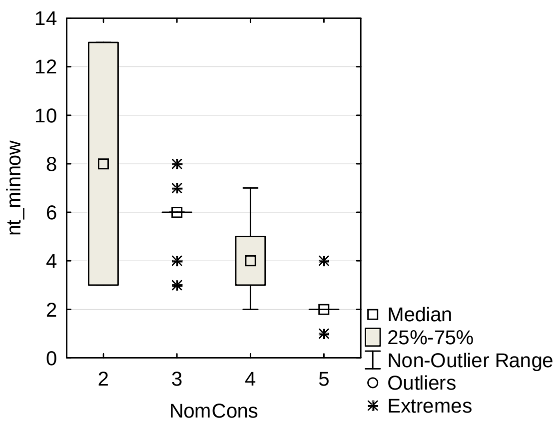
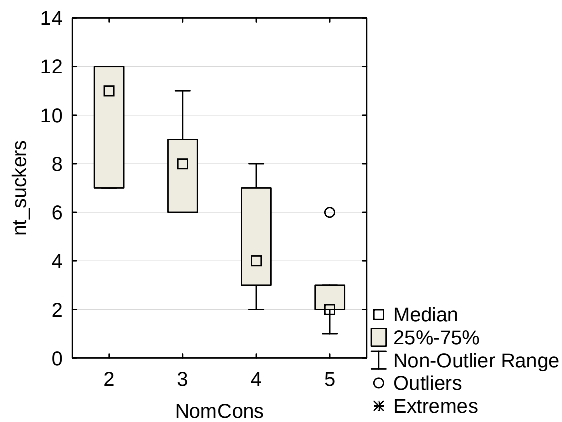
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_minnow
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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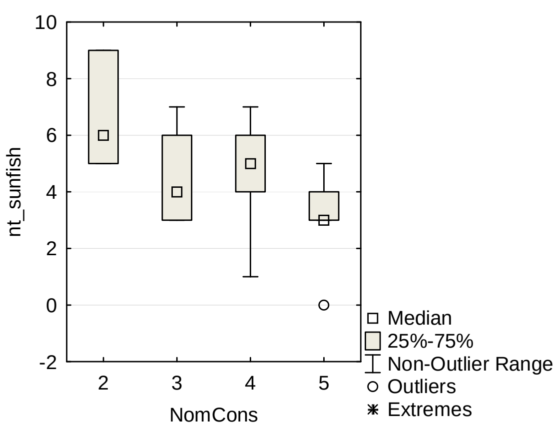
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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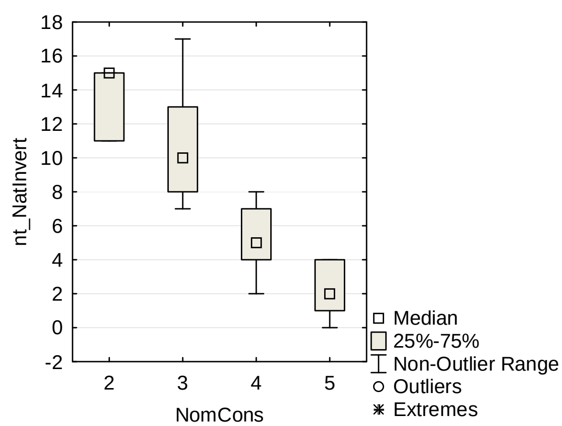
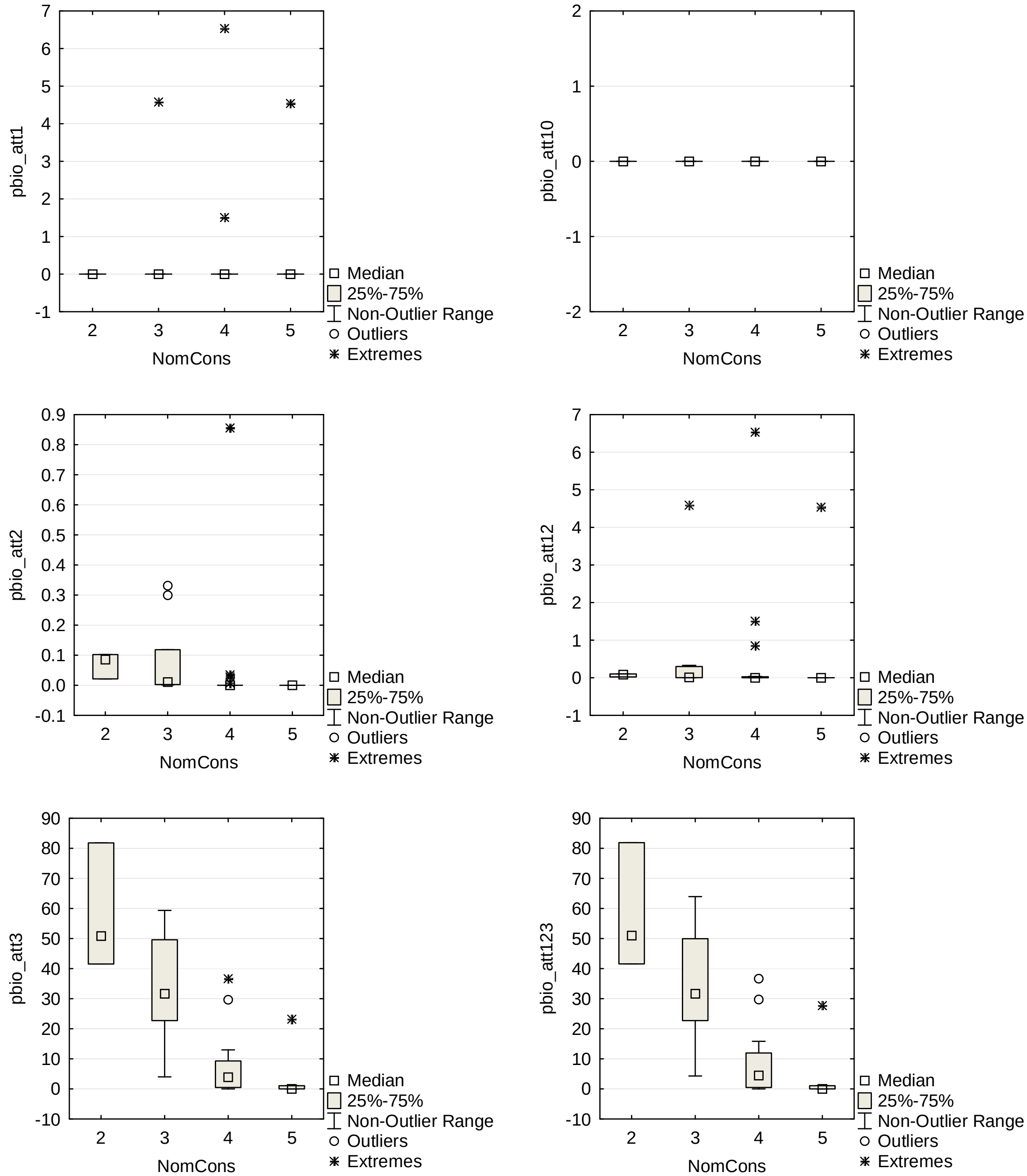
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_NatInvert
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att1
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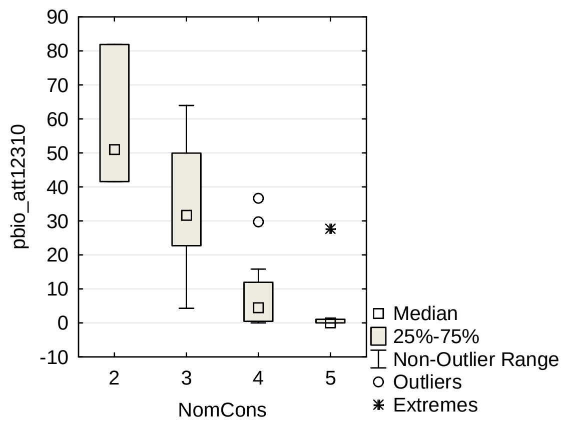
pbio_att2
pbio_att12
pbio_att3
pbio_att123
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att12310
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4
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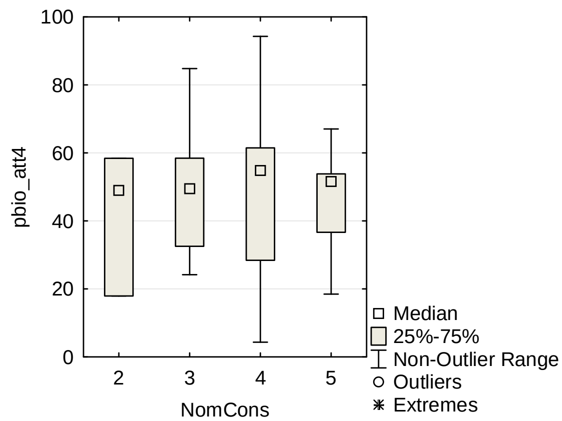
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att4
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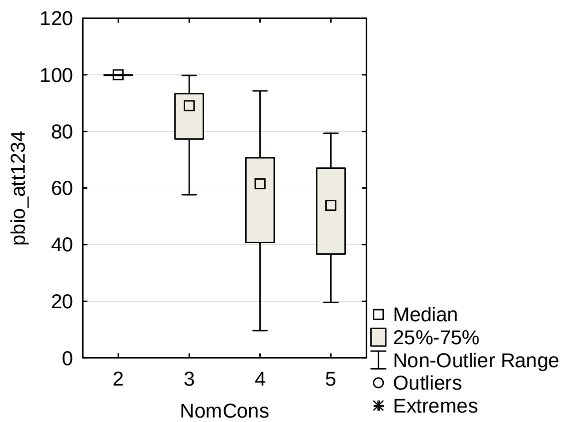
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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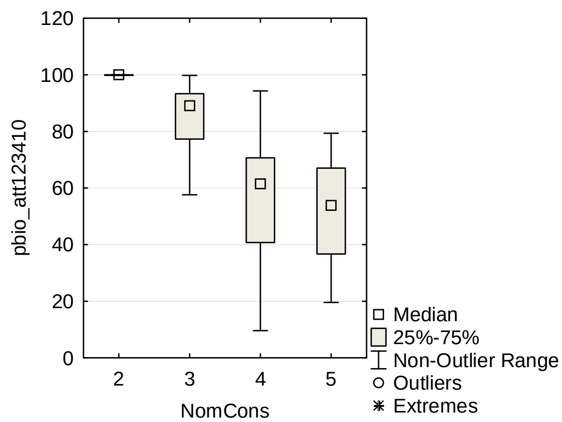
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att123410
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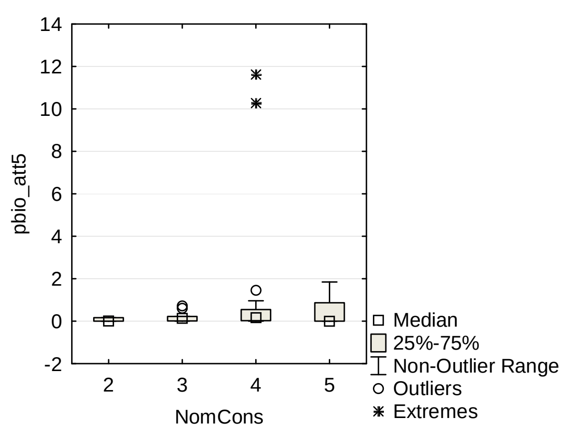
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att5
14
12
10
8
6
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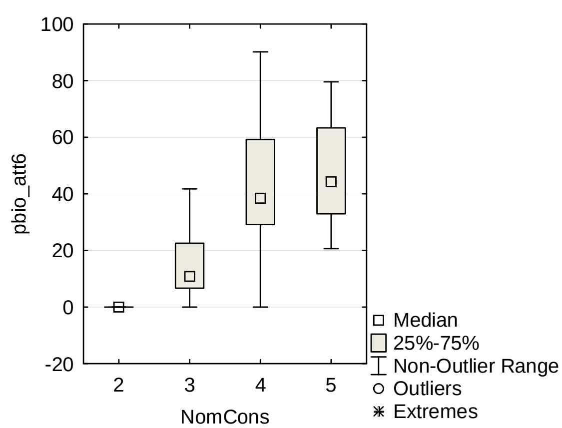
2
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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80
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40
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-20
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4
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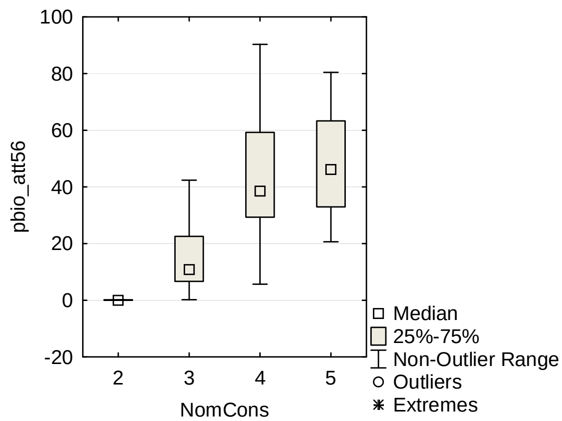
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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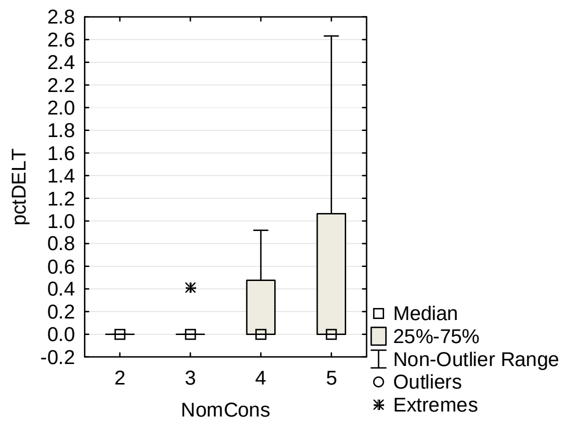
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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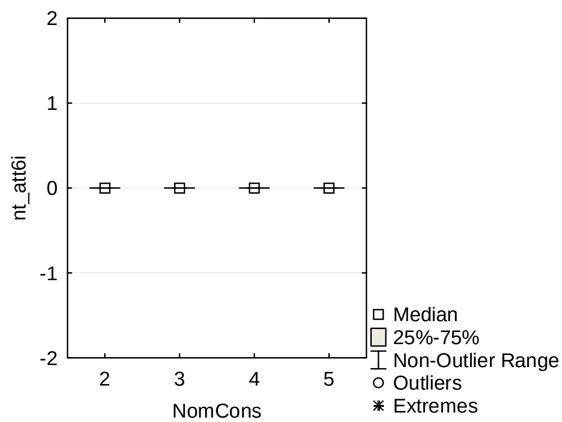
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
2
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_att6i
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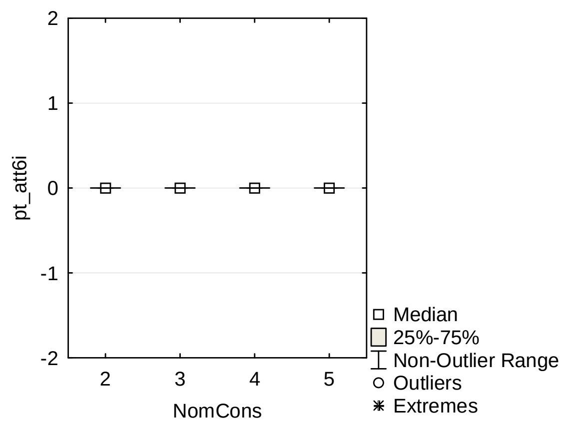
-2
2
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_att6i
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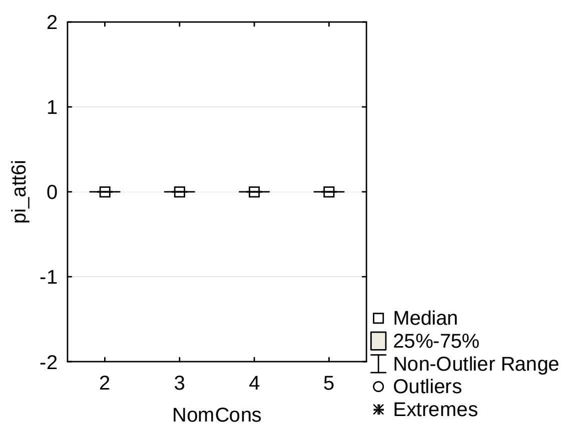
-2
2
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes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-2
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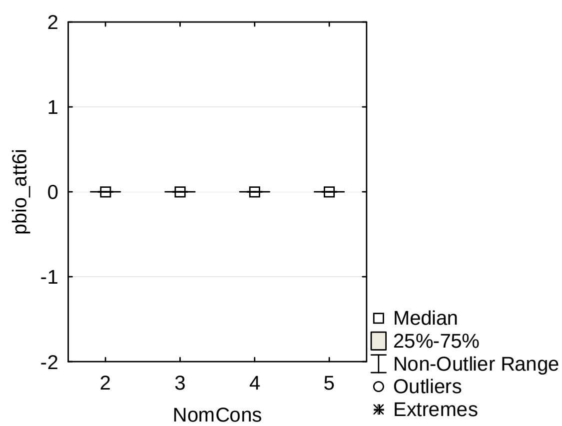
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pbio_att6i
2
1
0
-1
-2
2
3
4
5
NomCons
Median
25%-75%
Non-Outlier Range
Outliers
Extremes